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IRON AND STEEL ENGINEER

VOL. XV JULY • 1938 NO. VII

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Published Monthly by
ASSOCIATION OF IRON AND STEEL ENGINEERS
Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879. Single Copy $1.50
Subscription price in U. S. & Canada ..... $7.50 per year
Subscription price in foreign countries ..... $10.00 per year

PLASTIC BINDING U. S. PATENT NO. 1170285 LICENSE NO. 11

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Circular INGOT HEATING *Furnaces*

By L. R. KELLS

Salem Engineering Company

SALEM, OHIO

Presented before the A. I. & S. E. Chicago District Section, February 15, 1938

▲THE most important requirement in the heating of any steel is uniformity. By this we mean uniformity of temperature at all times during the heating cycle. In an attempt to accomplish this result, many types of furnaces have been built.

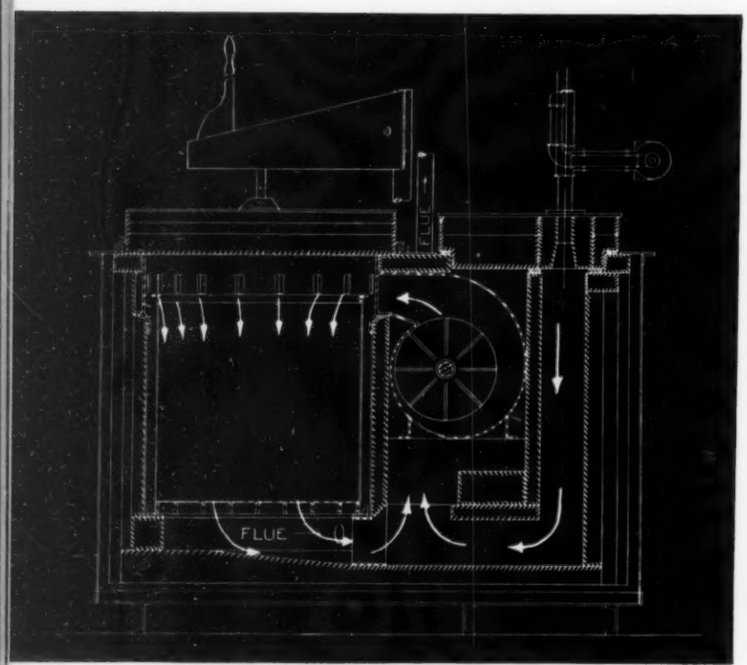
The gas recirculation forces set up in any heating furnace by natural means, that is, by the temperature head which will create circulation and therefore uniformity in the furnace, are quite small. These natural forces are usually under .05 in. water pressure.

In certain types of annealing furnaces, means have been incorporated for recirculating gases by a jet principle. In one case, the gases leaving the main burner block, went through a second block and in passing through this second block created a suction which, in turn, pulled gases from the furnace and diluted the gases entering the furnace. This accomplished both recirculation and tempering of the furnace gases and tended to create a uniform condition throughout the furnace.

In other cases, where the temperatures are not too high, a fan is used for setting up a mechanical and positive circulation. An outstanding example of this type of very uniform heating is the Lindberg furnace, Figure 1, which has been widely accepted within the last two or three years. The number of hot gas volume changes per minute are quite high in this apparatus, which accounts for the extreme uniformity.

Still another type of application, which has proved very successful, is the use of alloy fans in the case of hood, or cover, type furnaces, for positively setting up a circulation of the gases. This has resulted in a very much more uniform condition throughout the hood, and has increased the capacity greatly over the results which can be obtained without this mechanical means of gas recirculation.

FIGURE 1—Type of gas fired furnace widely accepted within the past two or three years. This cross section view shows how the fan is used for setting up a mechanical and positive circulation.



Several years ago, a new type of wire pit furnace was put in service in a plant in Ohio. This pit developed remarkable temperature uniformity throughout the entire unit and over the heating cycle. The similarity of the problem of heating pots of wire in a pit of this kind, and heating ingots, is obvious.

In other words, the question was asked—If it is possible to get certain remarkable uniformity in this wire pit type furnace, why could not this same principle of firing be applied to a furnace for heating ingots?

The answer to this question resulted in the design of the circular ingot heating furnace. However, there were many additional factors to consider since the ingot heating furnace must be operated at much higher temperatures than the wire pit.

In the circular ingot heating furnace, all firing is done through the sidewalls near the bottom of the furnace. The fuel is introduced into the furnace through a number of burners, each of relatively small capacity. The burners are placed in such a way that the burning gases leaving them and mixing with the partially spent gases in the furnace, impart a circular, whirling motion to all the gases.

Investigation of the angle at which these burners should be placed, created a very interesting problem. On the first experimental unit constructed at the Youngstown Sheet and Tube Plant, the angle from the radial line was about 23½ degrees. Subsequent installations have shown that an angle of 37½ degrees gives the correct combination for penetration of the gases leaving the burner with those in the furnace, and the whirling motion desired.

Location of the burners in one horizontal plane on the outside of the furnace near the bottom, makes them quite accessible. Inside of the furnace, a combustion "rim" is provided, so that complete combustion

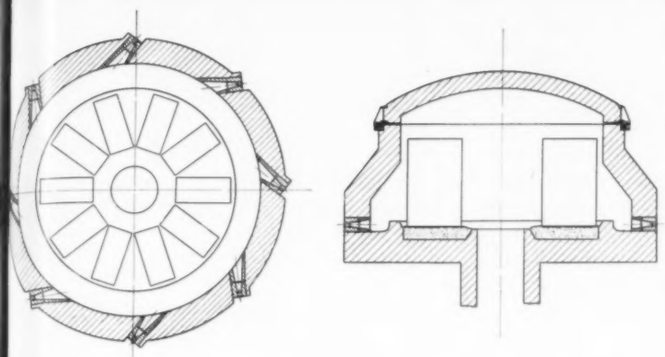


FIGURE 2—Combustion rim, provided inside the furnace, so that complete combustion may take place before any of the gases impinge upon the ingots.

may take place before any of the gases impinge upon the ingots. This is clearly shown in Figure 2.

The burner ports are made long, so that practically complete combustion takes place in them. In this way, the fuel is burned at maximum efficiency and higher temperatures, without in any way impinging on, or injuring the ingot being heated.

Gases which already have come in contact with the ingot and have given up part of their heat, form a blanket or cushion between the hot gases emitting from a burner, and thus temper the temperature of the two gases. It is this temperature of mixed gases which is used to control the flow of fuel to the furnace.

The one control pyrometer is located just above one of the burners—it makes no difference which one—and actually measures the temperature of the combustion products which are coming in contact with the ingots. The temperature measurement is therefore direct and need not be corrected by allowance for drops, or for averages occurring in other designs.

As nearly as we have been able to determine, the whirling action of the gases takes place in the furnace at a rate of about 50 ft. per second, and the gases make at least two complete (and possibly more) revolutions in the furnace prior to leaving through the waste gas outlet in the center bottom of the furnace.

The gases, therefore, travel at least 100 ft. before leaving the furnace, which is from three to ten times as far as is traveled in any other type of ingot heating equipment. The fact that the active heating gases do not have to turn square corners, but are always moving in a spiral path, makes a high rate of circulation possible with relatively low burner velocities. There are no stagnant pockets of gas, as all gases circulate at a uniformly high speed.

The travel of the gases is also independent of the time in the furnace, since the motion is "mechanical" and not dependent upon natural forces.

It is quite obvious in this unit that a considerable amount of uniformity and heating are due to convection heating, as well as to radiation heating, because of the high velocity of the gases impinging upon and surrounding the ingots being heated. Radiation losses

Key to all the various types of brick used in furnace illustrated in Figure 3.

	HIGH ALUMINA BRICK
	HIGH ALUMINA BRICK
	FIRST GRADE FIREBRICK
	LIGHT REFRACTORY BRICK
	INSULATING BRICK
	CHROME BRICK
	PLASTIC CHROME ORE
	PLASTIC FIRE BRICK

FIGURE 3—Improved section of circular ingot heating furnace.

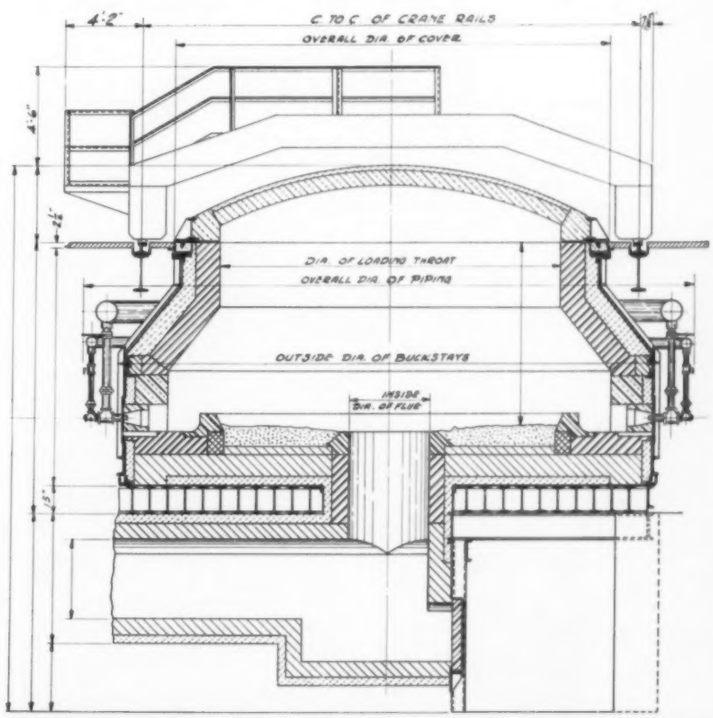


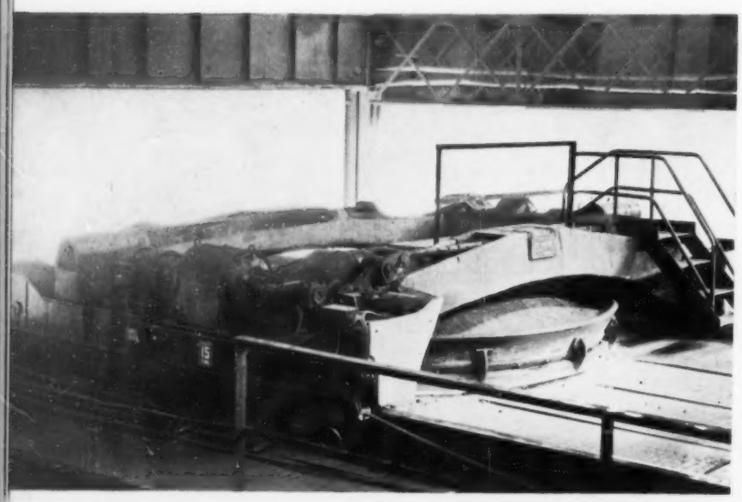
FIGURE 4—Battery of nine circular heating furnaces installed at Inland Steel Company.

from the furnace occur in three directions—upwards, outward, and downward.

Since the burners are located on the outer shell, all radiation from the gases to the brickwork, and then to the shell, is supplied directly by the burners without in any way affecting the heating of the ingot. There is, therefore, no limit from this source as to the maximum size of the furnace.

The circular form in which the furnace is built is a logical design which has many advantages. The maximum furnace area which can be enclosed by the minimum wall is in the form of a circle. The greatest strength which can be obtained from any material of which a furnace is to be built, is obtained in a circular form. The circular ingot heating furnace uses this full

FIGURE 5—The bridge of the cover crane is moved into position over the top of a furnace and in this position limit switches operate which permit the crane operator to raise the cover eight inches vertically.



centered arch construction throughout. The furnace itself is in this form, the burner ports are in this form, and the dome over the furnace is also in this form. Walls throughout the furnace are made uniform in thickness and properly insulated, which insures that each brick is getting the proper amount of cooling for long life.

The circular form utilizes the sidewall steel in tension, which is the strongest construction for the minimum amount of steel. No expansion joints in the brickwork are used. Provision is made for the outward expansion of the circular form in at least four places, depending upon the size of the unit.

The cover over the furnace is in the form of a dome, the very strongest construction that can possibly be used as a cover on any unit. These domes are made of 13½ in. of firebrick, covered with 2½ in. of insulation, and several in use three years are in extremely good condition.

The rim of the cover is made of heavy structural sections, protected by a special casting. The whole construction as now built, is supported upon the sand seal rim which, in turn, is supported by the shell of the furnace.

Since the sandseal is on the outside of the furnace around its circumference, and is cooled by exposure to air, there have been none of the troubles from this source, such as commonly occur with any metallic type of sandseal placed on a common wall between the pit holes.

In the first unit built, the usual slag or cinder cleaning holes were provided in the bottom of the furnace for the removal of cinder. The amount of cinder to be removed was so small that on subsequent installations, these holes have been omitted, and all cinder is removed through the waste gas port in the center of the furnace. The furnace bottom needs to be made every two to fourteen days, depending upon the amount of hot top steel heated.

At the bottom of the waste gas flue, a door is provided for access to it. In a modern installation this door is about three feet above the cinder tunnel floor, so that cinder may be raked directly from this level into a car, or into wheelbarrows.

The amount of cinder formed is not more than one wheelbarrow load per cleaning. Therefore, the task of keeping a furnace in good condition is minimized.

As will be observed from Figure 4, the cover mechanism is of a type which serves more than one hole. This has proven to be a very desirable feature for several reasons.

The first cost of the installation is reduced by not having so many cover lifting units. It is possible by this type of unit to move the covers longitudinally of the pit building, therefore saving space and making the unit entirely independent of column spacing. In use, the cover is moved in either direction a little over one-half the diameter of the furnace.

Then too, it has been possible, because less cover cranes are needed, to make a much better lift than has heretofore been used in connection with soaking pits. Salem Engineering Company's cover lifting mechanism is built by a crane manufacturer. Both Shaw-Box Crane and Hoist Company, and Alliance Machine Company have built units of this kind for us,

and we have had no trouble on any of the units. Figures 5 and 6 show such cranes.

The bridge of the cover crane is moved into position over the top of a furnace and in this position limit switches operate which permit the crane operator to raise the cover 8 in. vertically.

When the cover is raised to its full height, the limit switches are automatically reset, so that it is possible to move the cover crane and the cover to one side or the other.

It is impossible, when the crane is not actually over the pit, for the operator to place the cover on the pit flooring. It must be returned to the proper position before he can lower the cover. This makes the operation of the unit quite simple.

In Figure 7, please note the angle along side of the cover crane rail. This angle operates the limit switches for stopping a crane in the lifting position and for preventing lowering of the cover any place except over the furnace.

The number of cover lifting cranes should be the same as the number of ingot cranes. On large installations it is desirable to have one extra unit to be used as a spare.

Since the building of the first experiental unit, there have been a few changes made to the circular ingot heating furnace. Such changes have not been changes in design, but have been refinements in construction.

The first ingot heating furnaces of this type were built with the shell vertical (Figure 8) and a large mass of brickwork was used to fill in over the combustion rim, so that the top brickwork would be brought to floor level.

The sand seal was supported on this mass of brickwork and the entire weight of the cover dome, which was resting on this sand seal, was also carried by the brickwork.

Figure 9 shows an improvement as incorporated in furnaces built in England. The weight of the cover is finally carried by the shell of the furnace. The vertical shell is still retained.

Figure 3 shows the furnace as it is now being built. Note the excellent support for the cover crane and the clear floor provided.

The burner tunnels were made flat on top and covered by jack arches which gave trouble, due to high temperatures and the material used. As the need for these changes became apparent, they have been corrected.

The shell of the pit is now made in the form of a jug. The sand seal is carried on the neck of this jug, and transmits its weight and the weight of the cover which rests on the sand seal, directly to the furnace binding steel.

This has removed the extra load which was imposed by the cover resting upon the knuckle brick in the throat of the furnace. In some cases burner ports have been retained as originally built and super refractories used in their construction, which has entirely eliminated all trouble from this source.

In all recent furnaces, the port is made in the form of a complete circle, carrying out the general idea of the pit itself, and this is giving excellent results. See Figure 11.

It is remarkable that more changes have not been found desirable, which speaks well for the soundness of the original design.

By making the changes outlined above, a condition is obtained which is very desirable. The usual bloom rails which are shown in the illustrations for supporting the cover crane, may be eliminated and a heavy beam run through entirely independent of any of the furnace binding steel. On top of this beam, a regular standard railroad rail is used. This rail may be placed flush with the floor, so that when an ingot is withdrawn from the pit, it is only necessary that it clear the floor. Figure 3 illustrates this.

This also improves the appearance of the installation and is a much cleaner cut and more direct job.

FIGURE 6—When the cover is raised to its full height, the limit switches are automatically reset, so that it is possible to move the cover crane or the cover to one side or the other.

FIGURE 7—The angle at the left side of the illustration operates the limit switches for stopping a crane in the lifting position and for preventing lowering of the cover any place except over the furnace.

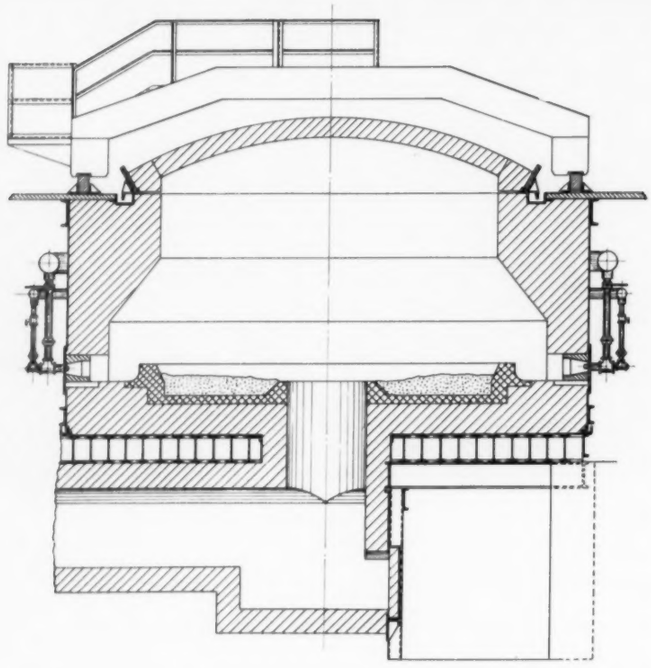
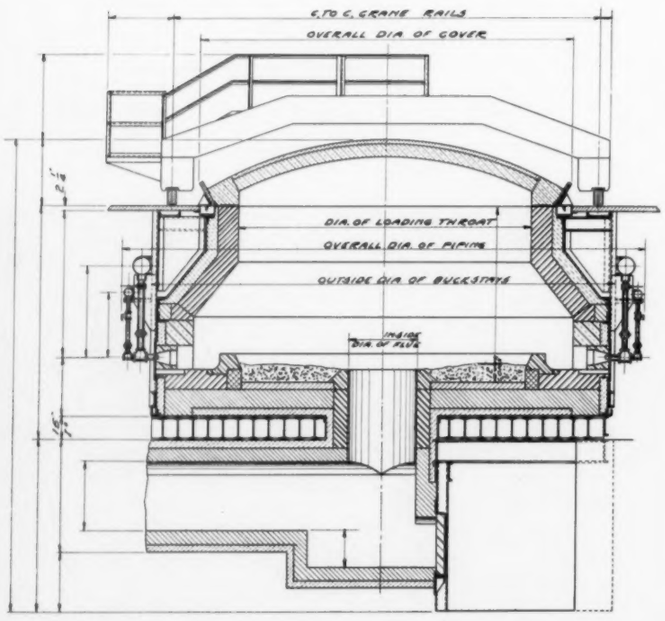


FIGURE 8—Circular furnace with the shell vertical and a large mass of brickwork used to fill in over the combustion rim, so that the top brickwork would be brought to floor level.

FIGURE 9—Improvements incorporated in this English built furnace has the weight of the cover finally carried by the shell of the furnace and still retaining the vertical shell.


C. TO C. CRANE RAILS
OVERALL DIA. OF COVER
DIA. OF LOADING THROAT
OVERALL DIA. OF PIPING
OUTSIDE DIA. OF BUCKSTAYS
INSIDE DIA. OF FLUE

The circular ingot heating furnace is offered in several sizes: 11 ft., 12 ft., 14 ft., 16 ft., 18 ft., in diameter. This diameter refers to the throat, or portion of the furnace which is open and visible from the operating floor.

There seems to be no difference in heating qualities between the different sized units. At present we have found it particularly economical to build the 11 ft. and 16 ft. sizes.

Any fuel seems to be satisfactory for use in the furnace. Units are now operating on oil, natural gas, coke oven gas, a mixture of natural gas and air, a mixture of coke oven gas and blast furnace gas down to a value of about 270 Btu. per cubic foot, and units are now being built to use hot, raw producer gas.

On one illustration the fuels are coke oven gas and oil, either one being used, depending upon the supply of coke oven gas. It has been found that the heating is a little faster with oil than with coke oven gas, the reason being that the capacity of the burners for oil in this particular unit, is greater than the capacity of the burners for gas, and the oil flame is more luminous than the gas flame.

Designs are available for use with low Btu. fuels, such as blast furnace gas and preheated air. In one layout, all preliminary work has been completed for using straight coke oven gas to straight blast furnace gas, or any combination of the two.

Low calorific fuels (below 270 Btu. per cubic foot) require the use of preheated air for obtaining the desired flame or pit temperature. For this purpose, we have placed a recuperator in the flue between the furnace and the stack at some distance from the furnace, to preheat the air.

The amount of preheat required, depends upon the leanness of the fuel to be used. However, due to the principle upon which the furnace is built and operated, it is possible to use a very high air preheat with high Btu. value fuels, with no danger whatever of the steel being incorrectly heated.

There is no need for limiting the amount of preheat, so that if a recuperator large enough for preheating air to, say 1600 degrees for use with blast furnace gas is installed, this same recuperator delivering practically the same air temperature, may be used with coke oven or natural gas.

Flame temperatures developed in the burner blocks will be higher with the high Btu. value fuel and ports must be built of materials which will stand such higher temperatures.

The brickwork in the furnace will not be adversely affected by the higher Btu. fuels and preheated air, since the temperature of the furnace is controlled directly by the fuel input. A distinct advantage in the low Btu. fuels in the circular ingot heating furnace is apparent, because the fuels have the space in which to burn before the gases come in contact with the ingots being heated. This allows complete combustion to take place before the fuel and air mixture is cooled below its ignition point by the cold ingots.

With small burners, intimate mixing of fuel and air is obtained and combustion is completed in a relatively short distance. This lends itself well to the burning of low Btu. value fuel, as well as preventing local heating when high Btu. fuels are used.

The long combustion or burner tunnel possible, because of the angle at which the burners enter the furnace, is another desirable feature which aids in getting maximum temperature from low value fuels.

It is well known that in port type furnaces, blast furnace gas and cold air may be burned and a temperature of 1800 degrees or 1900 degrees F. reached. With correctly designed burners, temperatures of 2150 degrees F. may be reached with cold blast furnace gas and cold air.

In blast furnace stoves, cold blast furnace gas and cold air produce temperatures in some cases upwards of 2200 degrees F. It is therefore apparent that the intimate and violent mixing of blast furnace gas and air is essential if maximum temperatures are to be reached.

For a given flame temperature, the air preheat does not need to be as high with burner operation, as it does if a port is used.

As previously stated, the recuperator is located some distance from the furnace. The stack flue then serves as a chamber to help remove deposits of iron oxide and dust before they enter the recuperator. The deposit seems to occur mostly at the time of placing coke braize in the pit bottom. The small use of coke braize necessary, (between five and ten pounds per ton of ingots) to maintain a bottom in the circular furnace, minimizes the total deposits.

Several types of recuperators are available to us for use with these furnaces. One is the vertical flue type recuperator, widely used throughout the steel industry. Another is the Carborundum tube recuperator, and a third, a metallic unit.

FIGURE 11—In all recent furnaces the port is made in the form of a complete circle, carrying out the general idea of the pit itself and giving excellent results.

Waste heat boilers may be used in connection with circular ingot heating furnaces. When this is done, usually three or four furnaces are hooked together, so that the waste gases pass through one boiler. Each furnace will develop 120 to 125 boiler horsepower under normal operation. Therefore, for four units, the size of the boiler would compare favorably with the size of a fire tube boiler now in use on a 100-ton open hearth furnace. The rating would be somewhat higher because of the higher temperature of gases entering the boiler.

Circular furnaces are in operation using a stub stack —top 3 ft. above charging floor—and no stack damper.

FIGURE 10—This shows the jack arches over the burner tunnels as originally built.

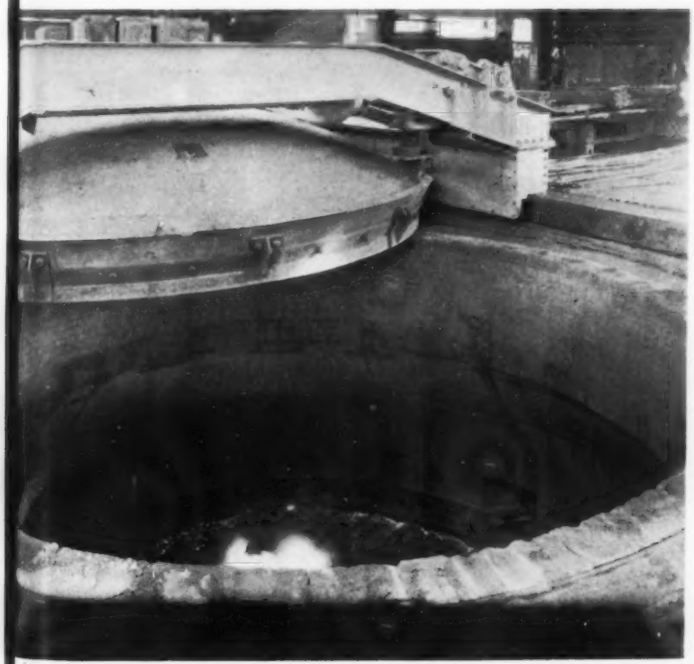
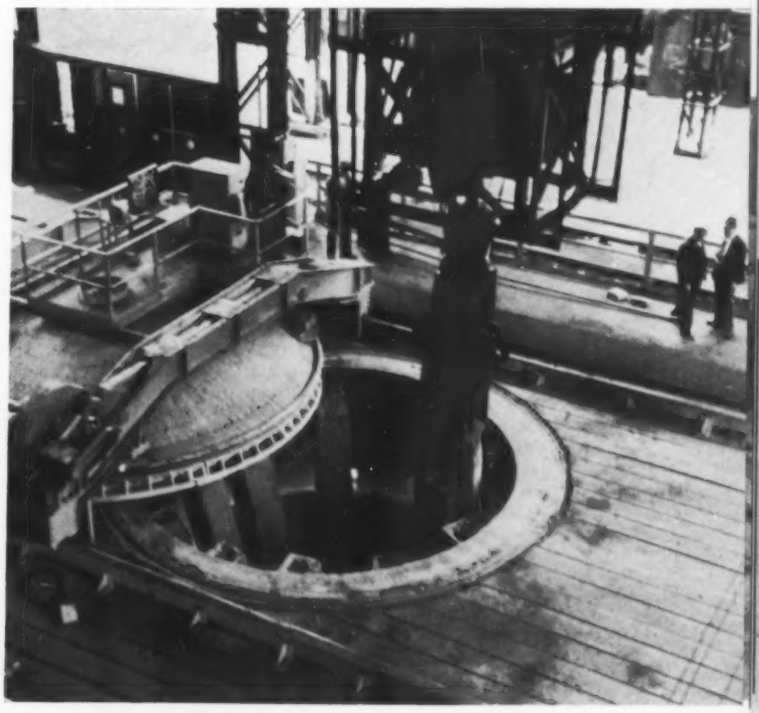


FIGURE 12—One of the units installed at the Lancashire Steel Corp., Irlam works, near Manchester, England.



They are also in operation with individual stacks and with several furnaces connected to one chimney. Automatic furnaces pressure controls are used in these latter installations.

The spacing of circular ingot heating furnaces depends upon the fuel to be used. The average space required for a 16 ft. unit varies from 31 ft. 9 in. to 34 ft. 6 in. center to center. The overall height of the furnace from the lowest point in the tunnel, where cinder is raked out, to the top is no more than the older type of regenerative unit. The depth of the pit is made about 8 in. more than the longest ingot, including its hot top. A desirable installation can, therefore, be obtained when replacing existing equipment, because it is usually possible to utilize existing foundations, as well as crane equipment.

The number of ingots which may be charged in a circular furnace depends upon the size of the ingots and is limited by the ability of the crane bits to get between the ingots.

Ingots 19 in. x 21 in. in section are normally placed in the 16 ft. furnace in two rows, or a total of 30 ingots. Occasionally, as many as 43 ingots of this size are charged in one hole. In this case, the ingots are leaned against the sidewall of the pit and against each other. The maximum number of ingots may be safely heated at one time in a given space in a circular ingot heating furnace.

The controls are the same as those used on any heat treating furnace. They are according to their importance:—Pressure control, temperature control, and combustion control.

The pressure in the furnace itself is made to operate a stack damper, which holds the desired furnace pressure as set by the heater. The temperature of the furnace is measured, as mentioned earlier in this paper, just above the burner level and in the furnace itself.

In this way, the actual furnace temperature is measured, which temperature corresponds to the active heating gases that are coming in contact with the ingots being heated. This insures that no damage will occur to the ingots because the furnace never reaches a higher temperature than that set by the pyrometer.

The supply of fuel to the furnace is regulated by the temperature requirement. The combustion is controlled by any one of several means, ranging from inspirating type burners and zero governors, to accurate air-gas ratio metering.

We have found that the furnace operates well with about one-half of one percent combustibles in the waste gases leaving the furnace. There are several reliable types of control available for any of the functions mentioned above. A few with which we are most familiar are Hagan, Leeds and Northrup, Brown, and Askania.

In order to secure a sensitive type of pressure control, the furnace pressure is balanced against the atmospheric pressure just outside of the furnace. The terminal of the outside pressure impulse line is arranged so that air currents do not cause a false reading. By thus balancing the pressures, the furnace may be held at any desired pressure within a few thousandths of an inch.

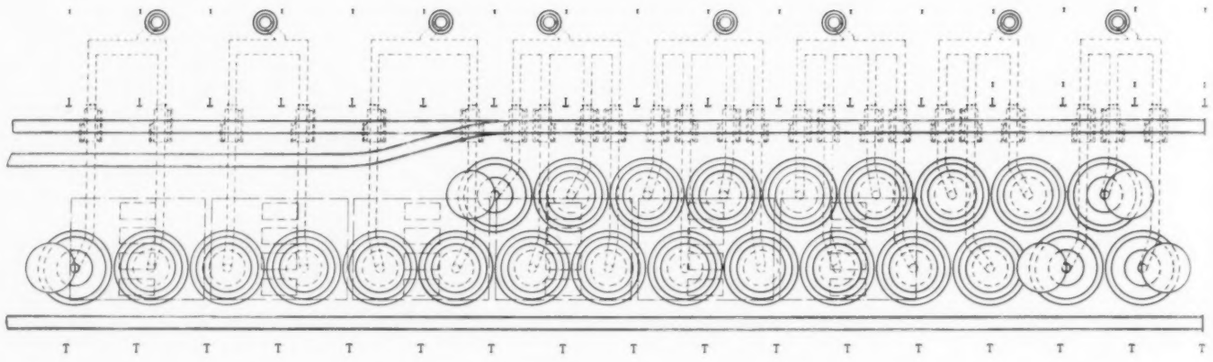


FIGURE 13—This shows the possibility of installing a large number of furnaces in an existing furnace building. Note the small space occupied by the recuperators.

Temperatures are controlled by any one of several makes of recording controllers. A single thermocouple is used to actuate the control instrument. The control power unit may be made to increase or decrease either the fuel or air flow. Our experience has shown that a type of control employing a full floating principle, that is one in which the fuel is turned up or down, but never entirely turned off, gives the best results.

While there are almost an unlimited number of combustion control combinations, for the sake of brevity only two will be described.

The Hagan combustion control shown in Figure 16 is for a combination of oil or gas.

Considering first the firing of gas only, the rate at which gas is supplied to the burners will be measured by the differential across an orifice in the gas line, this

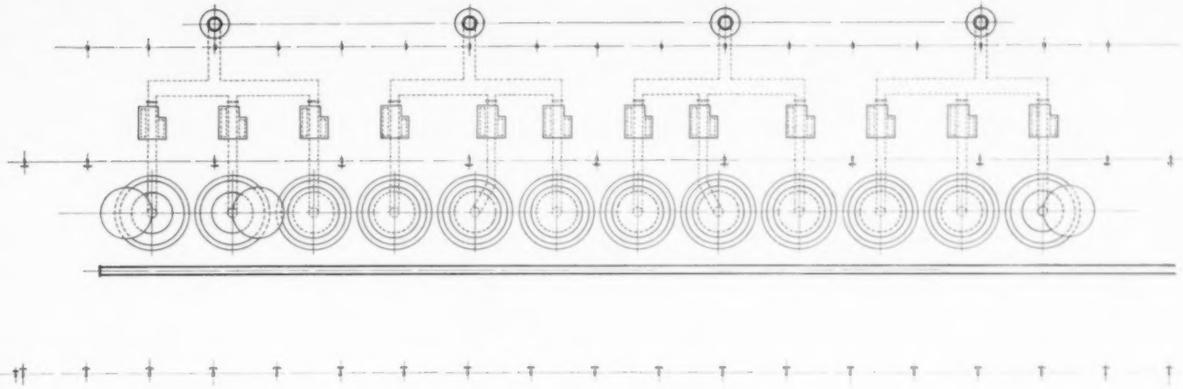


FIGURE 14—Typical layout of circular ingot heating furnaces using tubular recuperators for preheating the air.

differential being imposed upon the outer or loading diaphragm of a double diaphragm oil operated regulator.

In a like manner the rate of air supply to the burners will be measured by the differential across an orifice in the forced draft air duct system, this differential being imposed upon the inner or controlling diaphragm of same regulator. The ratio to be maintained between gas and air will be determined by the relative position of the movable fulcrum incorporated in the ratio regulator.

Departures of the ratio of gas and air from the adjusted standard will cause the ratio regulator to send oil pressure impulses to either end of a power cylinder.

The piston rod of this power cylinder will be connected through suitable mechanical linkage for operation of a control damper in the discharge of the blower. Thus, the quantity of air supplied to the burners will be maintained constantly in the desired ratio to the quantity of gas fuel being supplied.

The position of the movable fulcrum in the ratio regulator may be changed as desired to maintain the proper atmosphere within the furnace. This adjustment may be made without interfering with automatic functions of the ratio regulator, and a suitably calibrated indicating gauge mounted adjacent to the regulator will serve as a guide for the operators to indicate the extent and direction of any manual adjustment.

The rate of supply of fuel oil will be measured by means of the oil differential transformer installed in the oil supply manifold. All oil being fired will pass through the oil differential transformer in which is incorporated an adjustable orifice valve. The differential established across the orifice valve of the transformer will cause the transformer to establish a loading pressure varying directly with the differential set up by the rate of oil flow.

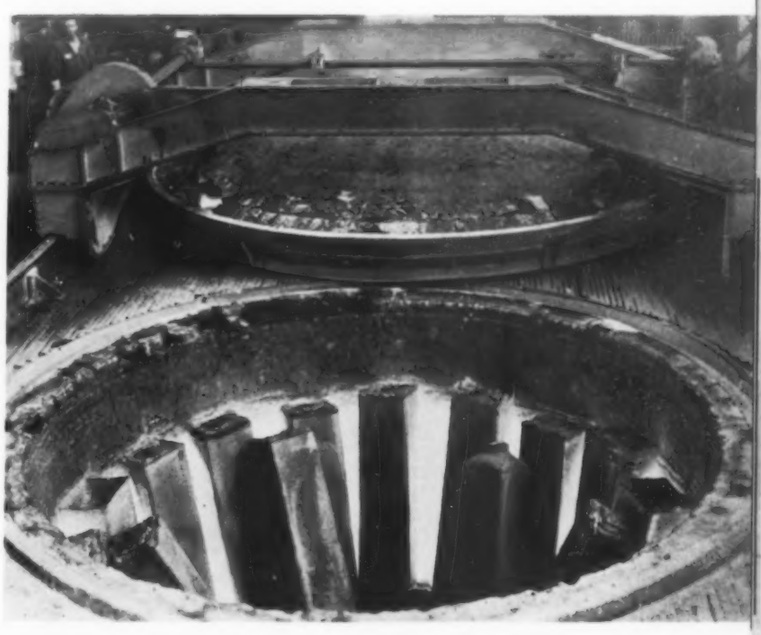
The loading pressure from the transformer will be imposed upon a loading bellows attached to the outer or loading diaphragm of the ratio regulator.

The effect of the loading pressure upon the ratio regulator will be exactly the same as the effect of the differential established by the rate of gas flow. Thus during periods of oil firing, the ratio regulator will maintain the desired relationship between the rate of oil supply and the rate of air supply in the manner previously described.

Figure 17 shows an Askania combustion control for a variable Btu. gas and air. It is premised upon a relationship which exists between the specific gravity and the Btu. value of a mixture of any two gases, each of a constant specific gravity and Btu. content.

The control functions as follows. A regular ratio regulator proportions the gas and air by controlling a butterfly valve in the air or in some cases the gas line.

FIGURE 15—This illustrates the possibility of charging as many as 43 ingots in three rows. The usual charge is about 30 ingots in two rows.



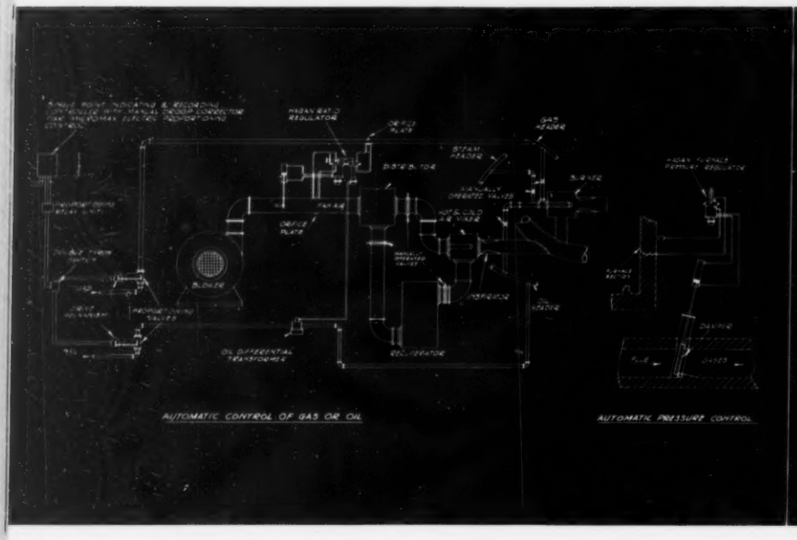


FIGURE 16—Schematic arrangement of the type of combustion control for a combination of oil or gas.

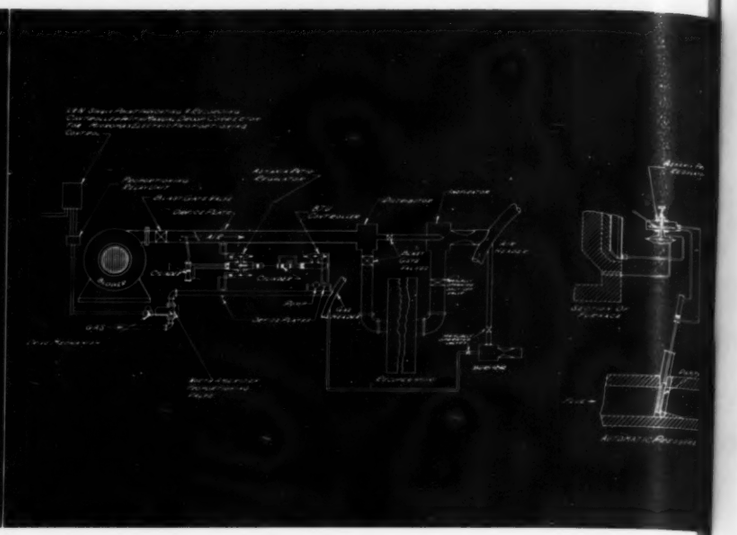


FIGURE 17—Schematic arrangement of the type of combustion control for a variable Btu. gas and air.

For the correction of this combustion or ratio regulator, a density recorder gives a differential impulse proportional to the gas density and creates a positioning of the correcting piston "A" in accordance with any density changes. The density correcting regulator operates on a whiffle-tree arrangement, the other end of which is actuated by the usual manual fuel-air ratio adjustment. The relation existing between the specific gravity of the gas and its Btu. value is plotted and the extent of correction made so that the desired air gas ratios will be maintained regardless of Btu. fluctuations in the fuel supply. One master density recorder can be made to correct the gas-air ratios on a large number of ratio regulators.

Other means of accomplishing these results are available, but to describe them should be the subject of another paper.

Figure 18 shows a typical panel board as made and used by the Hagan Corporation.

Figure 19 shows a control panel for Askania controls. All necessary functions for the control of pit firing and

FIGURE 18—Typical panel board used for the type of control shown in Figure 16.

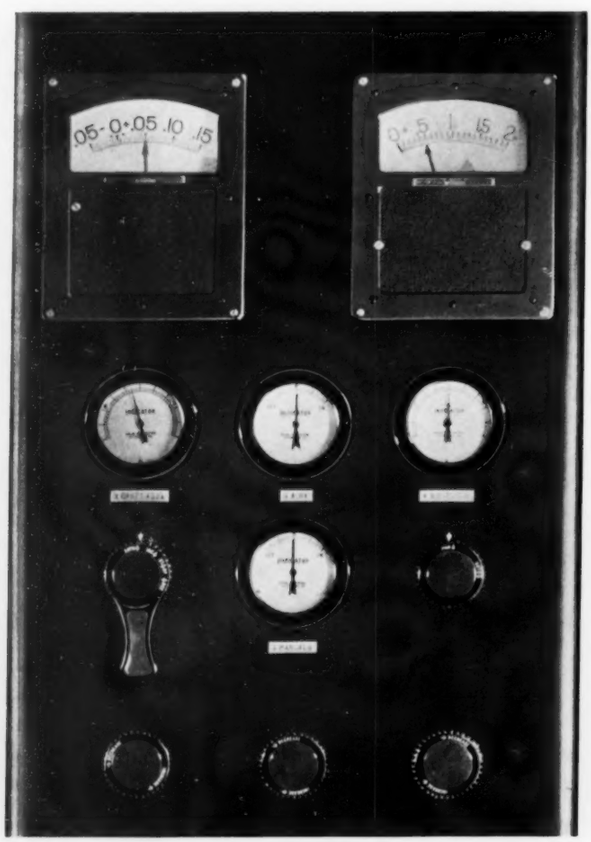
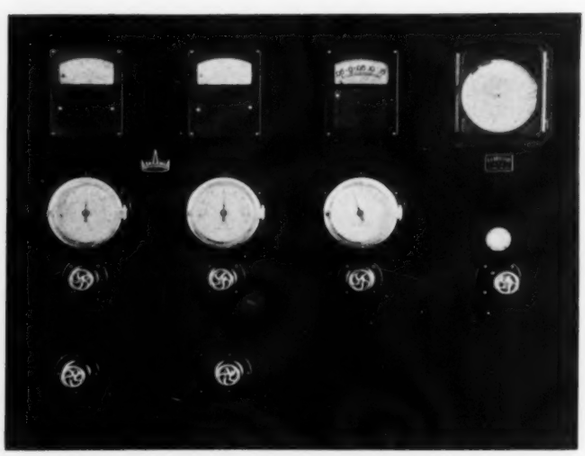


FIGURE 19—Typical panel board used for the type of control shown in Figure 17.

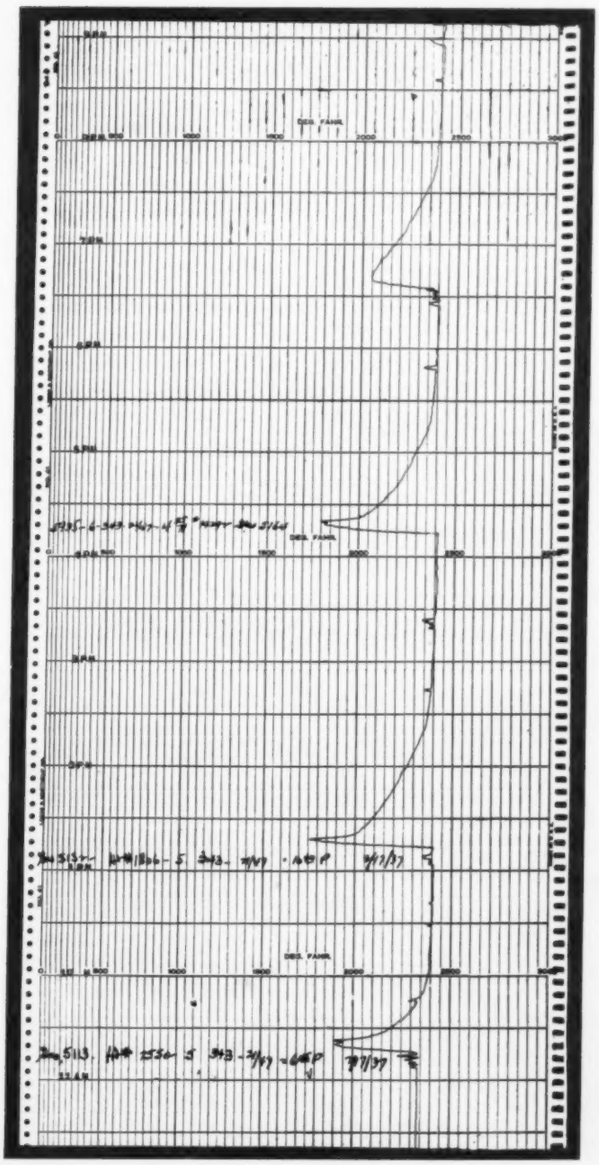


pressure are brought to these control points in a modern installation.

A fourth control may be added to this list, and that is one in which the fuel is turned down whenever the cover is moved, which may be accomplished manually or automatically as desired. It is not nearly so essential to shut off the fuel in the circular ingot heating furnace when the cover is opened, as in other types, because the firing is done entirely at the bottom of the ingots.

There is no danger to the ingot pit craneman should the fuel accidentally be turned on, as the flame will not impinge directly on the crane cab, and does not hamper a clear view of the ingots.

FIGURE 20—All temperature controls are equipped with this type of recording chart which gives the heater, metallurgist and the management accurate records of the furnace and ingot temperature at all times. The treatment given each heat is recorded and can be repeated any number of times.



If a type of steel is being heated that has required the cooling down of the furnace prior to being charged, the furnace temperature control may be manually set for the desired temperature, and gradually increased by the heater as the steel should increase in temperature.

This same result may be secured by the use of a program control. There is no need for a limiting rate of fuel flow to the furnace for any given period, since the flow is automatically controlled by the furnace temperature.

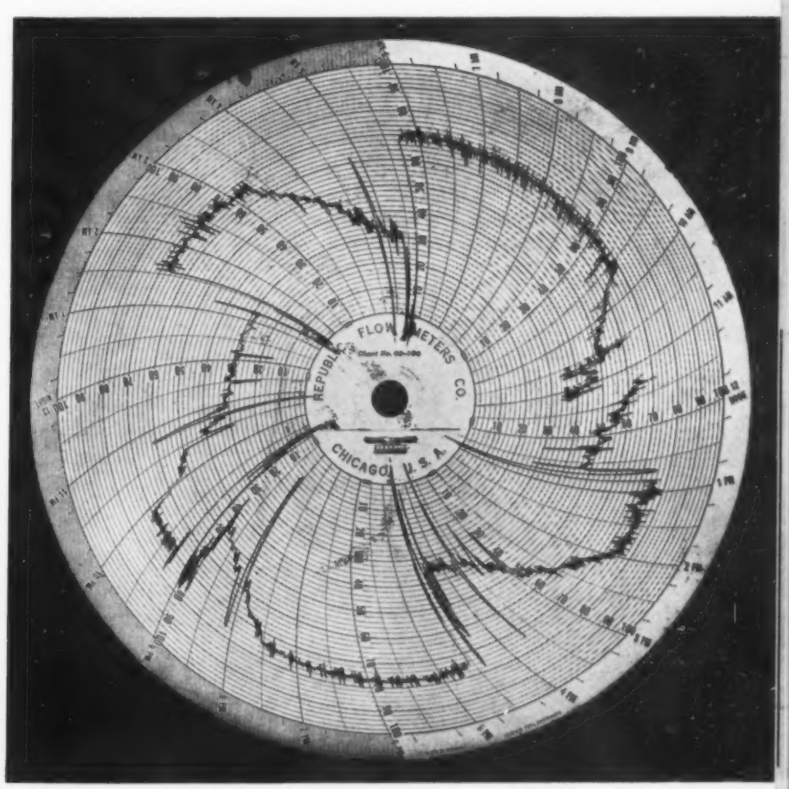
The temperature controls as supplied are equipped with recording charts, (Figure 20) which gives the heater, the metallurgist, and the management accurate records of the furnace and ingot temperature at all times. The treatment given each heat is recorded. This treatment can be duplicated any number of times.

If the metallurgical department desires to chart a heat and plot it on a temperature control chart, this exact cycle may be followed by the heater by simply changing the furnace temperature as desired. The temperature chart shown is run at half speed.

The temperature throughout the entire furnace is very uniform, in fact so uniform that commercial temperature measuring equipment will not detect any differences. With the cover removed, the furnace seems to be cooler in the upper part than in the bottom. However, this is due entirely to the removal of the cover and there is no effect when the cover is closed.

The temperature of each ingot is uniform from top

FIGURE 21—This chart denotes that the fuel rate is highest just after the furnace is charged. It remains at this point until the furnace has reached a temperature as set by the pyrometer control.



to bottom, and all ingots are always heated to the same temperature.

The furnace is exceptionally well adapted for the heating of cold steel. Cold steel may be safely heated at a fast rate in the circular furnace. There is only one method of heating by which steel may be heated in a shorter time, and this is the transfer of ingots from a pit to one still hotter.

Nine cold ingots, each weighing 26,000 pounds, or a total of 234,000 pounds in one 16 ft. hole, have been uniformly heated from cold to a rolling temperature of 2450 degrees in seven hours, fifteen minutes, without breaking the scale on the ingots or in any way damaging them.

Figure 21 shows that the fuel rate is highest just after the furnace is charged. It remains at this point until the furnace has reached a temperature as set by the pyrometer control. Then the control gradually cuts the fuel rate until the ingots are ready to be drawn from the furnace.

On this chart it is interesting to note that at several places the cover has been opened and the fuel shut off.

Please note that immediately the cover is closed, the gas rate goes to a high point, but promptly falls to the average flow line for the firing rate at the time the cover was removed.

The area in this small projection indicates the amount of gas used by the opening of the cover. In most cases the cover is not opened, or only partly opened, until the ingots are ready for rolling.

The fuel rate per ton of steel heated, ranges from 165,000 Btu. for hot Bessemer steel to about 2,000,000 Btu. for cold ingots, and the average without the use of recuperation of any kind, is about 1,300,000 Btu. This is based on approximately 75 per cent hot steel, and 25 per cent cold steel.

Day by day records are shown for a circular ingot heating furnace (Figure 22). This furnace is 11 ft. in diameter and operates in an installation containing two other types of pits. The furnace is not favored in loading or unloading, but must take its turn along with the other units. The heating for the days shown is typical.

It will be noted that with hot Bessemer steel the fuel consumption is as low as 166,000 Btu. per ton of steel heated, while for cold steel it runs to nearly 2,000,000 Btu. These figures are accomplished, it must be remembered, without the use of any heat salvaging device. The heating rate for a 16 ft. furnace is about 11 tons per hour for cold steel, and as high as 38 tons per hour for hot steel.

The circular ingot heating furnace makes many savings in the heating of ingots. There is usually a reduction of at least 1 per cent in scale. Edging cracks are among the defects which occur in rolling slab ingots when the ingots are improperly heated. Over regenerative practice, we have been able to reduce the edging cracks about 40 per cent.

Chipping costs have been reduced enough to pay the entire cost of the fuel used on the furnace. The extremely uniform heating of the ingots has reduced power cost and wear and tear on the mill and resulted in a superior finish for the steel as it leaves the mill.

The ability to heat cold steel in a minimum of time and without injury to the steel, is an outstanding characteristic of the circular ingot heating furnace. In fact it is not possible to "kill" this furnace by heating one charge after another of cold steel. They all heat in a uniformly short time. Actual fuel consumption compares favorably with any other type of unit.

Repairs and replacements are at a minimum over a three year period. The average cost of repairs of all kinds, both mechanical and refractory, on circular furnaces, is less than 1½ cents per ton of ingots heated. On one installation it is less than 1 cent per ton, which is about one-seventh to one-tenth the usual cost for such maintenance.

Due to the superior heating of the steel, the furnaces have shown that they actually increase the yield as much as 1 per cent, in addition to the scale saving.

Starting with a heat treating furnace as an ideal for the heating of ingots, it can be seen how thoroughly and satisfactorily the circular ingot heating furnace has accomplished these results. Not only have the results obtained in heat treating equipmnet been equaled, but this has been done at a moderate first cost.

FIGURE 22—Day by day records are shown for a circular ingot heating furnace, denoting heat number, time tapped, time in molds, etc.

Date	8/20/37	8/21/37	8/21/37	8/21/37	8/21/37	8/22/37
Heat No.	Bessemer	Bessemer	Bessemer	Bessemer	6274	2887
Time Tapped		Cold Steel			5:15 P. M.	1:05 A. M.
Time in Molds					1′ - 40″	1′ - 35″
Kind of Steel	108	108	108	108	348	154
No. of Ingots Charged	8	6	6	6	4	4
Size of Ingots	21 x 23	21 x 23	21 x 23	21 x 23	21 x 47	21 x 40
Weight of Ingots	8000	8,000	7200	7200	13,508	10,600
Time Charged	10:55 P. M.	2:50 A. M.	9:25 A. M.	1:30 P. M.	7:40 P. M.	3:40 A. M.
Time Drawn	2:30 A. M.	9:00 A. M.	1:05 P. M.	5:05 P. M.	11:05 P. M.	7:10 A. M.
Time in Pits	3′ - 35″	6′ - 10″	3′ - 50″	3′ - 35″	3′ - 25″	3′ - 30″
Tons Heated per Hr.	7.9	3.5	5.0	5.4	7.0	5.4
Total Gas Used B. T. U.	4,725,000	41,184,000	4,752,000	11,088,000	11,088,000	12,864,000
Gas per Ton Heated B. T. U.	165,780	1,924,480	246,210	574,500	460,080	677,050
Minutes from Tap to Charge in Pits					145	155

To the right is seen the train of six hot mill finishing stands of Republic Steel Corporations' new strip mill at Cleveland, Ohio. This mill, the largest and fastest in the world, will be inspected by members and guests of the A. I. & S. E. during the 34th annual convention and Iron and Steel Exposition in Cleveland, September 27, 28, 29 and 30. Below is a tentative list of the subjects to be discussed at the technical sessions during the convention.

"A Study of the Requirements of 440-Volt, A-C Motor Control for Steel Mills".

"Ward-Leonard Control for Blooming Mill Tables, Auxiliaries and Run-Out Tables of Hot Strip Mills".

"Electrolytic Pickling of Strip Steel".

"Pickling of Strip Steel from the Metallurgical Point of View".

"Continuous Pickling of Wide Strip Steel with Flash Welding".

"European Versus American Welding Practice".

"Welding as used in Industrial Plants".

"Finishing Equipment for Wide Strip Mills".

"Modern Blooming Mill Design".

"Rapid Acceleration and Deceleration of Cold Strip Mills with Metal in the Rolls".

"A Recent Development of a Low Voltage Rectifier for Industrial Requirements".

"Standardization of Steel Plant Fuel Accounting and Test Procedure for Fuel Consumption Determination".

"Oil Burning and Its Control".

"Use of Mixed Fuels for Melting and Heating of Steel".

"Design and Lubrication of Gears and Pinions".

"American and European Lubrication Practice for Steel Mills".

"New Developments in Oils and Greases used in E. P. Lubricants".

"Design and Operation of the Modern Blast Furnace".

"Modern Coke Oven Design and Practice".

Special PROBLEMS *of* STEEL MILL ELECTRIFICATION

By L. A. UMANSKY
Industrial Department
GENERAL ELECTRIC COMPANY
Schenectady, New York

Presented before the A. I. & S. E. Annual Spring Conference, Baltimore, Md., April 28 - 29, 1938

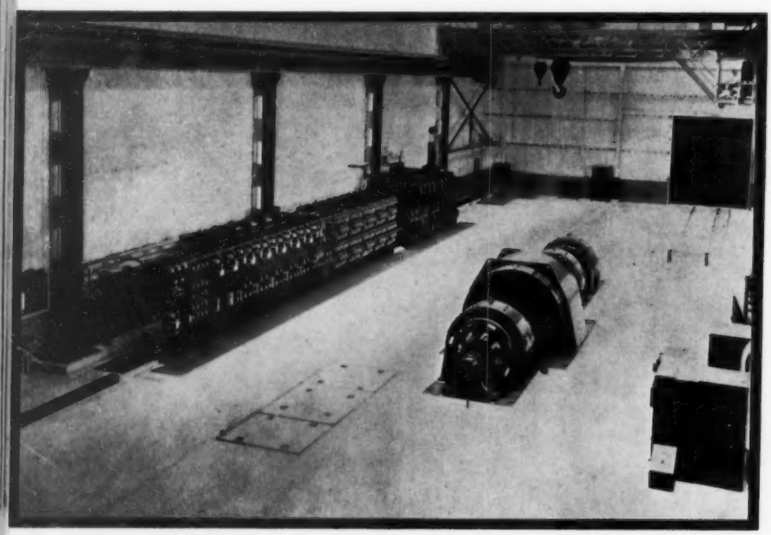
▲ SOME people are apt to think that the steel mill electric equipments are getting so standardized that not many new things can be looked for. Some even claim, for instance, that with so many strip mills already built the electric equipment for any new mill may be laid out with eyes closed and with every detail known in advance.

It is true that a great deal of experience has been gained, and that many details have taken a definite and generally recognized shape. There is little point in starting a new layout "from scratch," neglecting the lessons learned on the previous installations. But, it is radically wrong to assume that there are no more worlds to conquer.

We are always apt to do many things through force of habit, just because Mr. Jones or Mr. Smith has done it before, and "his mill is making money". We are apt to forget that we can do still better if we avoid some of Jones' or Smith's mistakes, and if we spend some little thought on how his mill can be improved, and how it can be better adapted to our needs. There is always room for improvements,—there is always a better way.

To illustrate these possibilities a few cases will be cited, all occurring within the last year, and each representing a definite step toward better operation.

FIGURE 1—Cold strip mill sub-station at Sparrows Point Plant, Bethlehem Steel Co., before the installation of frequency changer set.



25-60 CYCLE FREQUENCY CHANGER AND COLD MILL NO. 2

An interesting illustration of this ever-present opportunity to perform a known function in a somewhat off-standard, a little more efficient and better way, is the case of a cold strip mill substation at the Sparrows Point Plant of the Bethlehem Steel Company.

This substation originally included only a 3500 kw M-G set operating from 6600 volt, 25 cycle power supply (see Figure 1). The latter was primarily generated at the plant, but a tie-in with the 25 cycle public utility system has been also in service. Two 1250 kw, 600 volt generators on this set were supplying power to a 5-stand cold strip mill No. 1; a 1000 kw, 250 volt generator was used for general mill power.

In the latter part of 1936 two problems had to be solved. First, an additional cold strip mill was laid out, calling for 3500 kw, 600 volt d-c power. Second, the general growth of the plant, additions of a new hot strip mill, a rod mill, etc., required either additional generating capacity, or a stronger tie with the Power Company. Economic factors favored in this case the use of purchased power. Since the Power Company had only a limited amount of 25 cycle capacity, it became imperative to purchase power at 60 cycle. This brought into the picture a 25,000 kva frequency changer in order to tie-in the two sources of supply. The cold strip mill substation was the preferable location for this set.

To solve these two problems in the conventional manner would have meant the provision of a separate

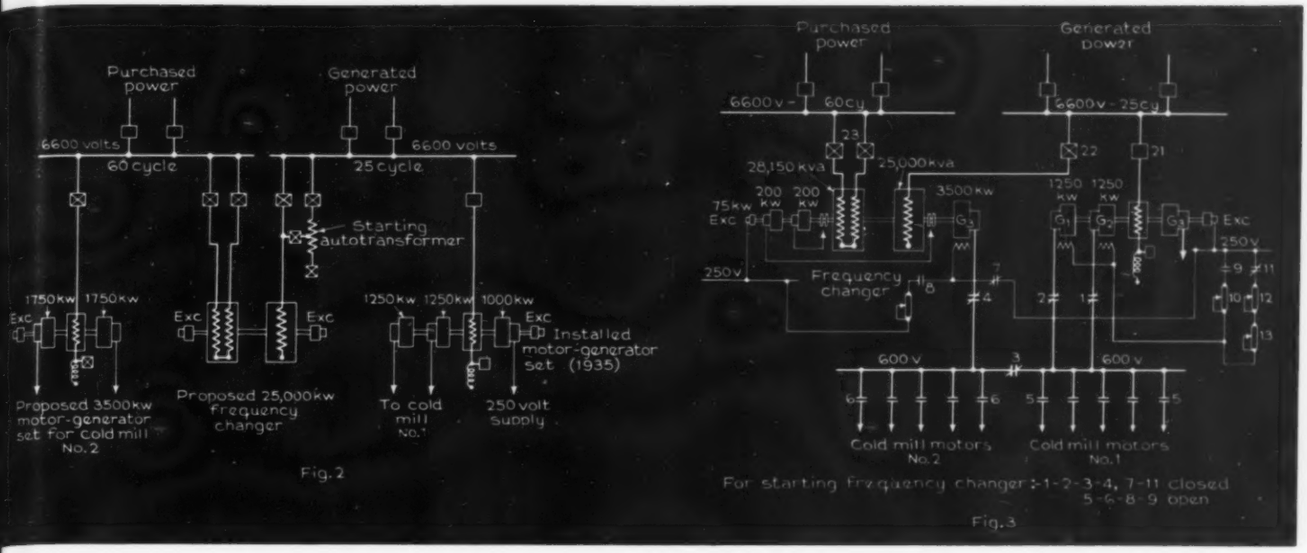


FIGURE 2—Conventional arrangement of adding to sub-station, Figure 1, the frequency changer and motor-generator for new cold mill.

FIGURE 3—Suggested and adopted arrangement of adding to sub-station, Figure 1, the frequency changer and d-c power for new cold mill.

3500 kw, 514 rpm M-G set with two 1750 kw generators for the cold mill No. 2, and of a 25/60 cycle frequency changer of the 300 rpm, synchronous-synchronous type. (See Figure 2.) The starting of this frequency changer on account of its size would be a problem in itself. The use of a starting auto-transformer, rather than a starting reactor, would be necessary. The new switchgear for these two sets would involve five 500,000 kva oil circuit breakers, plus three starting breakers. (It might be of interest to note, in passing, that the 25,000 kva, 60 cycle unit, with a rated current of about 2200 amperes, would normally require a 3000 ampere switch,— an off-standard rating for the metal clad assembly of 500,000 kva, 6600 volt units. Instead of this the stator winding of the 60 cycle unit is connected in two parallel circuits, each requiring a normal switch, duplicate of other units. At the 25 cycle side the normal 2000 ampere switch is easily rated up to 2200 amperes, on account of lower frequency.)

A thought occurred to discard this conventional arrangement in favor of the one on Figure 3.

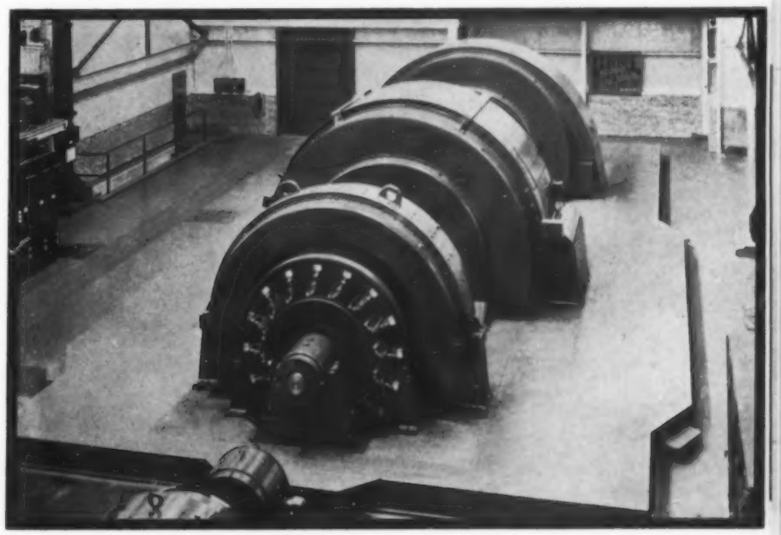
Instead of providing a separate 3500 kw set for the cold mill No. 2, a 3500 kw, 300 rpm, 600 volt generator has been added to the frequency changer. (Since the "normal" flow of power is from the 60 cycle to the 25 cycle system, the capacity of the 60 cycle unit has been increased to 28,150 kva.)

The same 3500 kw generator is used as a starting motor for bringing the frequency changer to speed and for synchronizing it. It is expected that this will be done normally once a week, if that often. The 600 volt buses of the two cold mills, old and new, are adjacent. For starting purposes the mill motor breakers (5) and (6) are, of course, open; while the tie breaker (3) and the generator breakers (1)-(2)-(4) are closed. Full field is applied to the 3500 kw generator. Voltage of generators (G1) and (G2) is gradually built-up by means of motor operated rheostat (12), in about two minutes, more or less. The frequency changer is brought to full speed. Automatic synchronizing equipment controls the vernier rheostat (13) and the subsequent closing of the oil switch (22). This puts the 25 cycle unit on the line.

As soon as this is done, the tie breaker (3) and the generator breakers trip out. The rheostats return to their normal positions. Either one or both mills may be put in service.

The next step is the automatic phasing out of the 60 cycle unit. Since this frequency changer is one of the several ones tying together the 25 cycle and 60

FIGURE 4—28,150/25,000 kva, 60/25 cycle, 6600 volt frequency changer installed at Sparrows Point Plant of the Bethlehem Steel Company. 3500 kw, 600 volt generator in foreground furnishes power to cold mill No. 2, and is also used for starting and synchronizing the frequency changer.



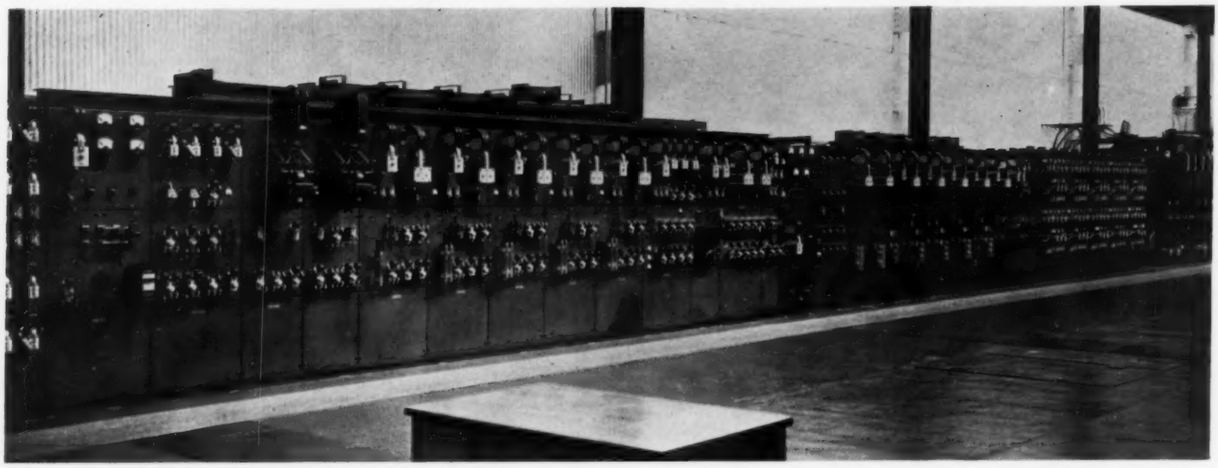


FIGURE 5—Control board for tandem cold strip mills 1 and 2, and for starting the 28,150/2500 kva frequency changer, at Sparrows Point Plant of the Bethlehem Steel Company.

cycle systems of this Public Utility, a motor operated phase shifter is provided on the 25 cycle unit of the set. A very interesting control equipment, specially developed for this purpose and to be described at some later date, is used to control this phase shifter automatically, and to close ultimately the breakers (23). An emergency provision is foreseen whereby the frequency changer may be started from the 25 cycle end by connecting it through one of the power lines to a generator at the power house.

Now, what has been gained by this arrangement? This question can be briefly answered as follows:

1. The first cost of rotating equipment has been reduced.
2. Floor space requirements have been greatly minimized.
3. The cost of foundation and of ventilating equipments have been reduced.
4. The number of oil circuit breakers has been reduced from 8 to 3.
5. The starting auto-transformer has been eliminated.
6. The frequency changer set is being started and synchronized in an extremely smooth and "painless" way, hardly noticeable on the power system.

In other words, a simpler and better arrangement has been provided at a lower cost.

VOLTAGE AND POWER FACTOR REGULATION AT HOT STRIP MILLS

A modern wide hot strip mill usually delivers strip, even from its finishing stands, at a higher speed than necessary from the tonnage viewpoint alone. This speed is determined by metallurgical factors. In other words, the ratio of time with metal in the rolls to the total time during which such mill is running is seldom greater than 50%. Quite often the "time factor" is down to 35% or less.

The effect of such operation on the driving equipment and on the power system is illustrated on Figure 6. It indicates the kw-load on three 6000 kw M-G sets supplying power to the finishing stands. When rolling wide sections, say 80-90 inches wide, at speeds 1600-1800 fpm, the finishing mill load will easily climb, in say 10 seconds, from about 1000 kw friction load to a peak as high as 30,000 kw. In another 10 seconds the load is down to 1000 kw, and so on.

If these sets are driven by 90% PF synchronous motors and they are operating in a conventional manner, with constant excitation, the leading kva given out by these three machines vary from 12,500 kva at no-load to practically zero at peak load. If the sets were driven by unity power factor motors, then the reactive kva would easily go to the lagging side.

These swings of load are apt to produce some undesirable effects on the voltage regulation of the power system. This is particularly so since the reactive kva also changes,—and in the wrong direction. Considering the reactive drop in the transmission lines, transformers, current limiting reactors, etc., the leading kva should be maintained or increased with the increase of load—which is contrary to what the machines do if left to themselves.

Calculations made for a recent installation show that it is desirable, from the viewpoint of good voltage regulation on this particular system, to increase the leading kva given out by these three sets by about 8000 kva when the load on these sets changes by some 30,000 kw. This means that excitation of the synchronous motors should vary automatically with load.

Figure 7 shows very clearly the effect of this arrangement. Curve (a) represents the combined reactive kva of the three sets if they operate with constant excitation. Curve (b) gives the reactive kva of the sets if their excitation is controlled automatically by a constant power factor regulator; curve (c) gives the corresponding excitation values. The regulator maintains a 90% PF through a load range from 5000 kw to 23,000 kw. Excitation is not reduced at loads below 5000 kw, and is not increased at loads above 23,000 kw. This arrangement just about gives us the needed increment of 8000 kva leading under the heavily fluctuating load. Quite obviously, many other regulator adjustments are also possible. For another mill now

under construction, the regulator will maintain an approximately constant value of leading kva at all loads, because in this case it will give the best voltage regulation on the mill bus.

Figure 8 shows the simplified diagram of connections. The excitation of the three 8550 hp synchronous motors is supplied by a 150 kw exciter. The latter has two fields (F1 and F2). (F1) gives the basic excitation required at light loads; (F2) gives the "compounding" effect as function of load. It is under control of a power factor regulator with responds to the combined power input to the three M-G sets.

The basic excitation in this case is sufficient to permit the synchronous motors to carry loads up to 165% normal. When temporarily overexcited under load for the sake of voltage regulation the machines are good for a pull-out torque of more than 250% normal. Thus, at any load, the peak capacity of the synchronous motors is more than ample.

The following question was raised in connection with this equipment: If the ultimate purpose is to maintain a fairly constant voltage at the mill bus, why not apply a voltage regulator which would automatically adjust the excitation of these large sets to obtain this constant voltage?

Such arrangement would be open to criticism. Assume, for instance, that the supply voltage drops below normal for several hours or days, for reasons beyond our control. The regulator would try to correct this condition, successfully or otherwise, by overexciting the synchronous motor possibly beyond the safe limit. If, on the other hand, the bus voltage is above normal, the regulator would try to underexcite the motors, possibly going to the limit in this direction, and yet without correcting the voltage. If in the meantime a heavy load would hit the mill the synchronous motors might fall out of step.

Thus, the "voltage regulator" arrangement is not as attractive as it might appear at first glance.

Various other ideas were also considered, all having the same purpose; i.e. to control the excitation of these large synchronous motors as function of load. For instance, d-c load relays can be readily provided in the circuit of each finishing mill motor. As the bar enters in succession these stands, the load relays pick up also in succession and cause the exciter voltage to go up in graduated steps. As the bars leave the stands, the opposite process takes place.

This scheme is quite simple and workable. The increments of excitation can be readily adjusted within any limits. The load relays are quite often on hand anyway, comprising for instance a part of the flying shear equipment. The scheme has one serious drawback, however: The load relays will pick up just as readily, and will apply the same synchronous motor excitation whether the finishing mill load is 25% normal or 150% normal. Thus, when the mill load is relatively light, the synchronous motors will get more excitation than they need, and therefore the bus voltage regulation will not be as good as with the scheme actually put in service.

The power factor regulator performs quite creditably, as expected. But it provides considerably more than merely a good voltage maintenance. By automatically reducing the motor excitation at light loads, the running light losses are very materially reduced. Assuming, for instance, a 96-inch hot mill and 5000 operating hours per year, and otherwise average rolling conditions, we can save as much as 300,000 kw-hours per year.

The wide mill for which the original equipment has been built operates on purchased power. The power contracts stipulate the lowesr rates when the power factor is held between unity and 90% leading. With 99% lagging or with 89% leading power factor the rates begin to go up. Now, if the synchronous motors of these large sets are left running with constant ex-

FIGURE 6—KW Load and reactive kva at three 6000 kw M-G sets furnishing power to finishing stands of a 98-inch hot strip mill.

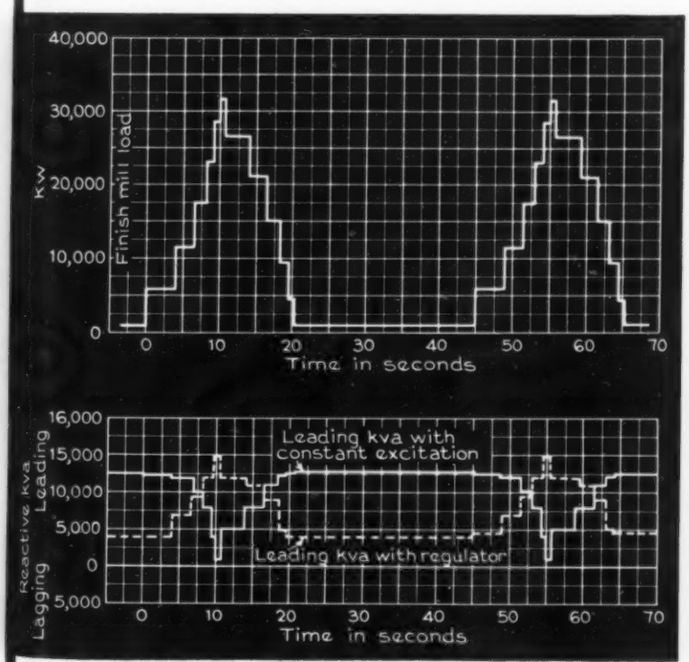
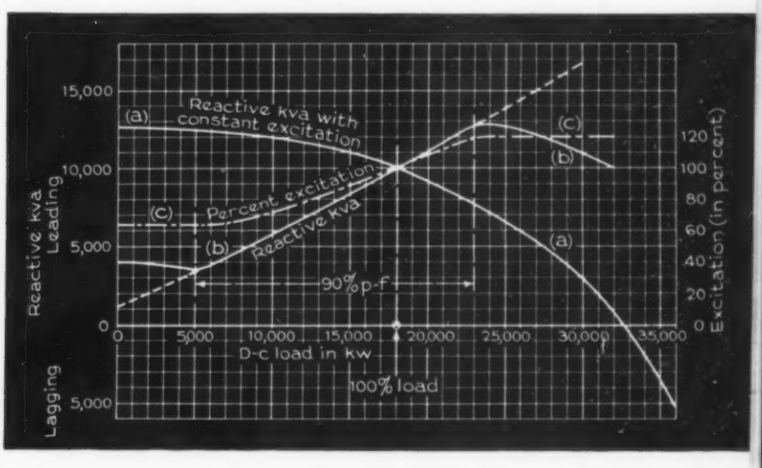


FIGURE 7—Effect of load and excitation of three 8550 hp synchronous motors (driving 6000 kw M-G sets) on reactive kva on incoming line. The M-G sets furnish power to finishing stands of a 98-inch hot strip mill.



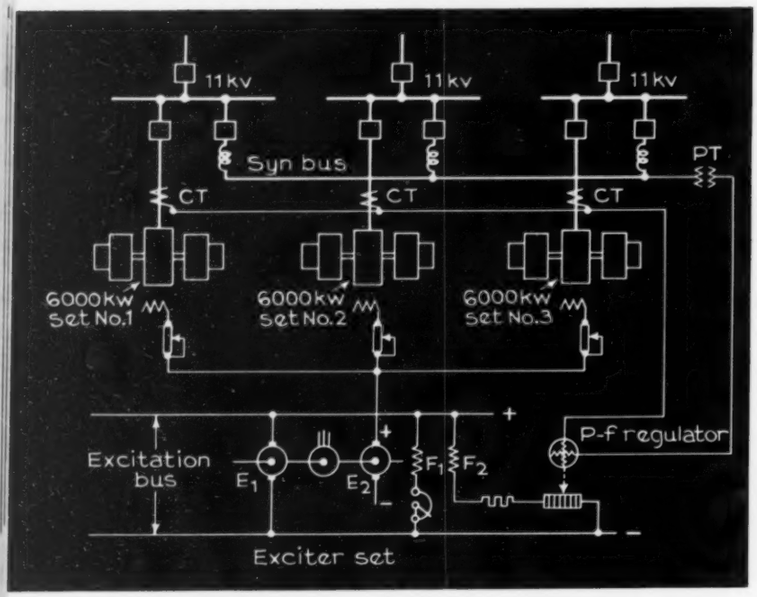
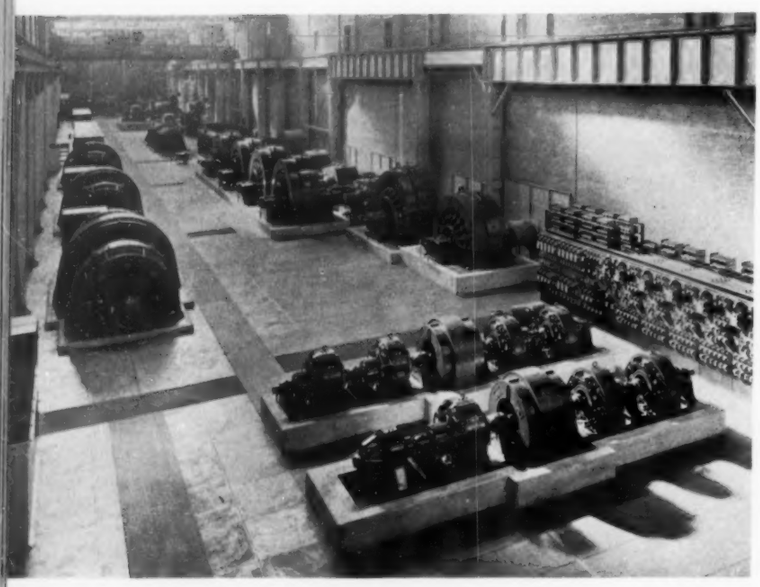


FIGURE 8—Automatic control of excitation of synchronous motors driving three 6000 kw M-G sets at 98-inch hot strip mill.

citation, and if the running light periods are relatively long,—the average power factor is apt to be too low (on the leading side), boosting the power bill. The regulator saves this extra tax. Thus, actually, the cost of the regulator will pay for itself several times over within the first year of operations. The good voltage regulation obtainable is "velvet".

FIGURE 9—Motor room at the 98-inch hot strip mill of Republic Steel Corporation, Cleveland, Ohio. Automatic control of excitation as function of load is used on synchronous motors driving three 6000 kw M-G sets.



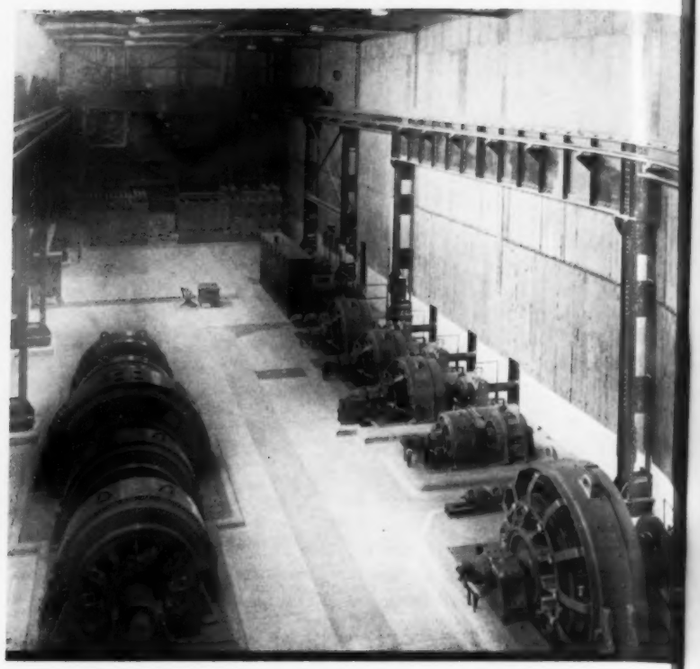


FIGURE 10—Motor room at the new No. 2 4-stand rod mill of Bethlehem Steel Company, Sparrows Point, Md., The M-G set carries three 1750 kw, 600 volt generators for main roll drives and a 1500 kw, 250 volt generator for auxiliary power.

FIELD FORCING OF SYNCHRONOUS MOTOR DRIVING ROUGHING STANDS

A 44-inch hot strip mill has four roughing stands, driven at a constant speed by separate motors. No broadsiding is to be done. The passes are relatively long. Flywheels would be of little use. 2500 hp synchronous motors were chosen for these drives.

Here again the question of excitation and pull-out torque was given consideration. With its rated excitation the 2500 hp motor is capable of developing up to 250% torque, or 6250 hp. Ordinarily, this is ample. However, if the slab is too cold, or if the supply voltage is abnormally low, the potential danger of pulling out of step is at hand.

It was decided, therefore, to normally operate these motors underexcited, which will be for 80-90% of total time. A limit switch is located a short distance ahead of each stand. When the slab hits the switch, full excitation, or overexcitation, is applied to the motor. After the slab passes over the limit switch, and a short time interval has elapsed, the overexcitation is removed. Incidentally, the same limit switches are used to control the water sprays for scale removal.

This simple outfit, of negligible cost, will help the operators very materially. In the first place, it made possible the use of 2500 hp motors with normal or 250% pull-out torque. Otherwise, either 3000 hp motors, or motors with 300% torque or more, would be considered, needlessly increasing the first cost. Secondly, operating the motors underexcited for 80-90% of total time provides, on a smaller scale, the same benefits, as were

noted in the previous example, namely: Reduces the losses, improves the voltage regulation.

FEWER AND BIGGER M-G SETS

Steel mill power systems grow in capacity. The required interrupting capacity of switchgear has to keep step with this growth. There can not be any compromise in this respect. The first cost of switchgear per circuit quite naturally goes up. This fact gives us a greater stimulus for trying to reduce, if possible, the number of required circuits. One method, by no means a new one, comes to our attention more forcibly than heretofore.

When a new mill is built we ordinarily need d-c power (usually at 600 volts) for the main drives, and 250 volt power for auxiliaries. Motor-generator sets are conventionally used for these purposes.

In order to save on the number of high voltage circuits, it is to our advantage to combine, within reason, as many generators on one set as is practicable.

For instance, the new rod mill at Sparrows Point requires for its main drives a total of three 1750 kw, 600 volt generators. (See Figure 10.) They are, of course, grouped together on one set. Furthermore, for 250 volt supply at the rod mills an additional 1500 kw capacity was needed to supplement the 2000 kw already on hand.

A 1500 kw generator was mounted on the same set with the 600 volt generators. Again, the cost of rotating equipment, foundations, and switchgear has been reduced.

The tendency in this direction is apparent. A new hot strip mill in the Chicago district will have each of the main 5000 kw M-G sets equipped with a 1000 kw, 250 volt generator, to bolster up to 250 volt system. Another strip mill likewise adds a 750 kw, 250 volt generator to the M-G set for main drives. A cold mill in Cleveland takes a similar step.

In all these cases the auxiliary generators on the main M-G sets were not the sole source of supply of 250 volt power. Thus, with the main M-G sets down, the 250 volt bus still can be energized; crane service, etc., is still available.

This list of special problems and of means of tackling them could be extended to almost any length. But this is not a record of achievement. It is merely an example of opportunities, waiting for us just around the corner. They are there for us—to take or to neglect. The choice is ours.

DISCUSSION

PRESENTED BY:

L. V. BLACK, Assistant Superintendent, Electrical Department, Bethlehem Steel Company, Bethlehem, Pennsylvania.

J. F. HEADLEE, Electrical Engineer, Carnegie-Illinois Steel Corporation, Gary, Indiana.

WRAY DUDLEY, Electrical Superintendent, National Tube Company, McKeesport, Pennsylvania.

L. V. BLACK: Mr. Umansky's paper was quite interesting in that it pointed out the economics in first cost and space factor to be realized when a problem is carefully checked from all angles.

The elimination of certain pieces of equipment such as a starting auto transformer, five out of eight oil circuit breakers, additional foundations and ventilating equipment surely is a step in the right direction as regards first cost and maintenance.

Adding the 3500 kw generator to the frequency set has the advantage of very easy starting of the frequency changer, and the elimination of the cost of an extra motor necessary for a motor generator set, but it has the disadvantage of tying up various pieces of apparatus in one unit, plus the injection of an additional coupling which adds to the ever present care and exactness of properly lining up a multiple unit set.

The control for automatic phasing out of the frequency changer will undoubtedly be a very interesting subject especially since the Sparrows Point plant lies in a territory subject to severe electrical storms. It will be interesting to learn how the control will function and what regulation can be expected with oscillating surges of power between the 25 and 60 cycle systems as may occur in the advent of trouble or disturbances from lightning.

In the early part of 1934 it became evident that additional generating capacity would be required at our Bethlehem Plant or some means be provided for the purchasing of additional power from the local Power Company for two (2) reasons:

1. Certain electrical units installed in the latter part of 1930 went into service on a reduced or part time operation due to a drop in the steel business, and not until the early part of 1934 did these units contribute any appreciable load to our general growth of plant load.

2. Certain contemplations of additional electric heat treating furnaces, electric arc furnaces, etc., at that time and which have since been installed would mean additional plant load.

Needless to say, that economic factors favored the use of purchased power.

A hydrogen cooled frequency converter was installed at the Power Company's substation adjacent to the plant, the unit being the first hydrogen cooled converter of its kind, a 300 rpm., 23500 kva., 90% P.F. 60 cycle motor, driving a 22222 kva., 90% P.F. 25 cycle generator, delivering power to our plant at 6900 volts, 3 phase, 25 cycles.

The conventional method of reduced voltage supplied from the main power transformer was employed for starting and bringing the unit up to speed, the unit being synchronized on the 25 cycle end, the converter delivering power to our plant in parallel with two (2) other frequency converters and steam turbines 38 miles distant from the hydrogen cooled unit.

The method of starting a frequency converter as outlined by Mr. Umansky certainly has many advantages both as to first cost of equipment, method of starting, etc. However, in our case, I think the Power Company was justified in designing the main transformer with reduced voltage taps to start the

(*Please turn to page 55*)

High Voltage
TRANSMISSION LINES *and* TOWERS
...AS RELATING TO STEEL MILL REQUIREMENTS

By E. L. PETERSON, Transmission Engineer

American Gas & Electric Company

NEW YORK, N. Y.

Presented before the A. I. & S. E. Pittsburgh District Section, December 17, 1937

▲ THE design and construction of transmission lines serving steel mills involve problems more difficult of solution than are met with in the customary open country lines. The location of the mills in congested industrial areas limits the available routes and frequently fixes the exact tower locations. On the average transmission line it is possible to locate towers on long tangents. Angle and dead-end structures are infrequent. Steel mill lines on the other hand are frequently tortuous in their routes. Each tower location imposes a problem of its own and duplication of structures becomes difficult. In addition to mechanical difficulties steel mill lines present electrical problems which are even more bothersome. As with all lines, the principal problem lies in the protection against lightning flashovers. Several approaches to this problem are being practiced today which will be discussed in this paper.

MECHANICAL DESIGN

No attempt will be made in this general paper to discuss in detail the many phases of the mechanical design of transmission lines. Brief mention will be made, however, of some of the fundamental considerations which apply to all steel tower transmission lines.

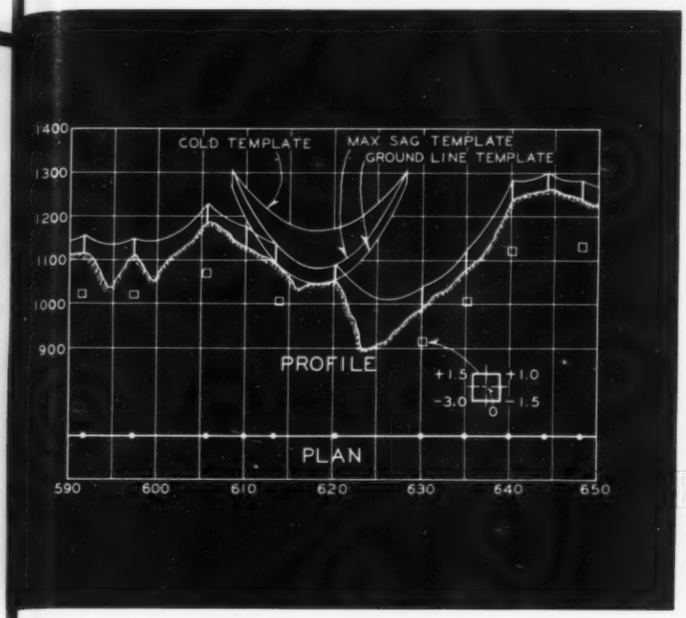
The first step in locating a line is to secure the best available maps of the area between the terminals of the line. The most frequently used are the U. S. Geological Survey Maps published by the Department of the Interior. These maps, generally drawn to a scale of 1 in. to the mile, are available for about one-half of the area of the United States. The approximate center line can be located on such maps to a sufficient accuracy to form the basis for a preliminary field survey. This survey will locate obstructions and right of way difficulties which must be detoured.

It is sometimes economical particularly on long lines to secure aerial photographic maps covering the proposed route. The pictures are taken at a height sufficient to cover a width of 1½ miles or more to allow for possible changes in the location of the center line. Enlargements of the photographs are made to the desired scale (frequently 1 in. equals 600 ft.) and are assembled so as to form a continuous strip map.

After the center line has been accurately determined, a detailed survey of the route of the line is made. Stakes are driven at all angle points and at a sufficient number of intermediate points to fix the exact center line. The location of these stakes with respect to the origin of the line is determined and this distance is marked on the stakes. Elevations of the ground are determined at intervals along the line so that an accurate profile can be made.

The field notes are transcribed to plan and profile maps which are used in locating the towers. On these maps all angles of the line are shown as well as the elevation of the ground surface. The maps also show all buildings, telegraph lines, and railroads which are crossed. It is customary to include also the property lines and the names of the property owners as well as data on the nature of the terrain, such as woods and areas under cultivation.

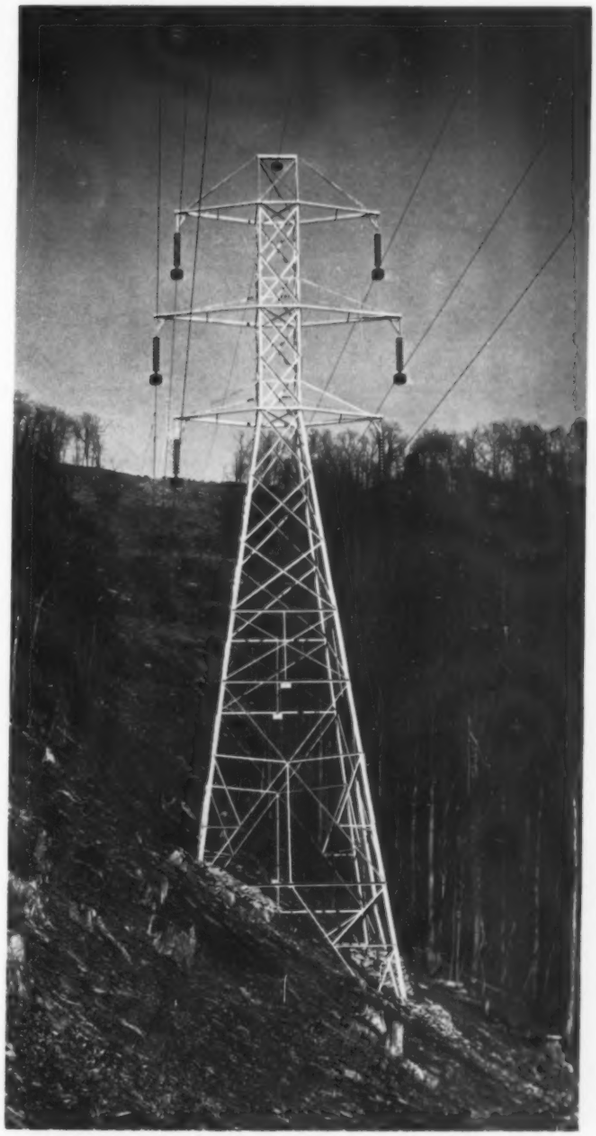
Figure 1 shows a simplified plan and profile map and also the customary method of locating towers by means of a templet. A parabolic curve is drawn up representing the maximum sag for all spans that are likely to be encountered on the line. The abscissae of the curve represents one-half of the span values and the ordinate represents the sag. A second curve is shown under the conductor sag curve at a distance equal to the ground clearance desired. It is convenient to transfer these curves to a transparent celluloid sheet. This templet can be slid along the profile, and by adjusting the ground clearance curve to clear the ground line, the towers can be located. It is frequently economical to install extensions to towers in order to obtain sufficient height to clear unusual conditions in the profile.



assumptions of conductor tension and tower spacing. The location restrictions of towers and the high ground clearances generally required of steel mill lines frequently require the use of high conductor tensions. In this part of the country the customary wire loading assumption is a wind force of eight pounds per linear foot acting on a wire covered with a ½ inch radial thickness of ice. Under this loading the conductor should not be stressed beyond the yield point of the cable.

The distance between conductors at the towers is governed by the line voltage and the length of span or sag. The National Electrical Safety Code gives the

FIGURE 1—Left—Simplified plan and profilic map and customary method of locating towers by means of a templet. FIGURE 2—Below—This illustrates the use of weights as a means attached to the suspension clamp of adding sufficient load to the insulator strings.



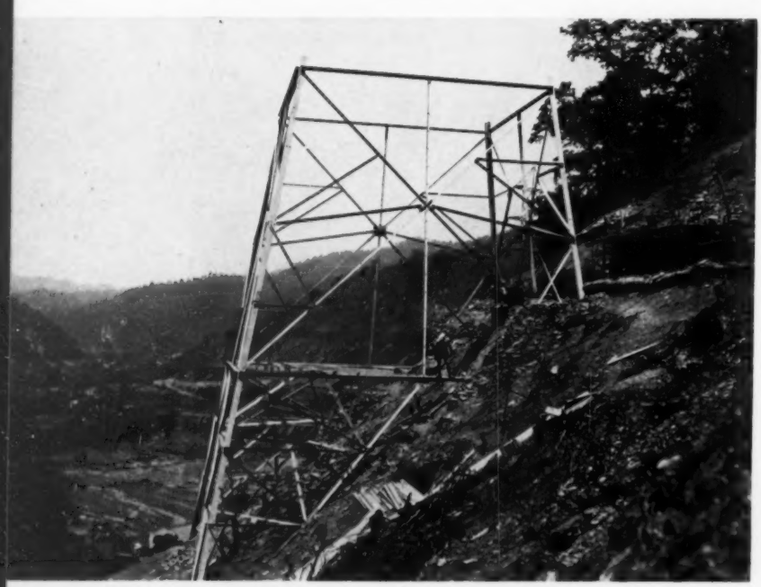
After the towers have been located by means of the maximum sag curve, it is desirable to apply a curve which represents the minimum sag values which will occur under cold weather conditions. The purpose is to determine possible uplift at the towers. Even where no uplift occurs, the amount of vertical load may be insufficient to prevent a suspension insulator string from swinging sideways an excessive amount thus reducing the clearance to the tower. It is frequently possible to add sufficient load to the insulator strings by means of weights attached to the suspension clamp. Figure 2 shows the use of such weights.

Except in flat country it is rare that all four legs of the tower intersect the ground line at the same elevation. If the difference in elevation is excessive, the anchor installation becomes expensive unless some form of sidehill extension is added to the tower. In order to determine the ground elevations at the four legs of the tower, it is often necessary to make an extra survey for this purpose. At the same time a check should be made on sidehill conditions under the span wires to make sure that proper clearances will be obtained when the wires swing sideways. It is preferable to obtain sidehill readings to determine conductor clearances during the original survey since this information may affect the location of the towers. Figures 3 and 4 show towers located on side hills where special sidehill extensions were found necessary.

CONDUCTORS

The conductor size is almost always determined by the electrical requirements. The strength of the conductor, however, is governed by considerations of span length, ground clearance, and economy of the supporting structures. No specific formula is applicable to determine the conductor tension and tower spacing which will produce the most economical line, and it is necessary to investigate the total cost using several

FIGURE 3—Above and FIGURE 4—Below—These are excellent examples of towers located on sidehills where special side hill extensions were found necessary.



minimum values of separation based on these variables. In most instances it will not be found necessary to exceed the Safety Code figures particularly on spans above 400 feet. On short spans the governing factor in conductor separation, where the wires are arranged vertically, is frequently the clearance between the conductor and a cross-arm member below it.

Where suspension insulators are used, it is necessary to provide a clearance from the conductor to the tower which, under all conditions, will equal or exceed in flashover value that of the insulator string. The clearance must take into account the deflection of the insulator string from a transverse wind load. The angle of swing of the insulator string should be calculated for each suspension tower or for the worst location where duplicate towers are used. Where towers are designed for a loading condition of eight pounds wind acting on a cable covered with a ½ inch ice, this loading may be used in calculating insulator deflections although the condition of an eight pound wind acting on a bare cable should also be investigated. The vertical load is the weight of the cable times the length of cable between the low points of the sag curves on the two adjacent spans. To this should be added one-half the weight of the insulator string. The transverse load is the wind force in pounds per linear foot acting on one-half the sum of the two adjacent spans. The tangent of the angle of deflection of the insulator string will be the transverse load divided by the vertical load.

Table 1 (1) gives the flashover characteristics of rod gaps based on a 1½ x 40 positive wave, which may be used to determine the required separation between the conductor and tower. The flashover value of 5¾ x 10 inch suspension insulators is given in Table 2. (1). By using these two tables a comparison may be obtained between the flashover value of the insulator string and the minimum flashover value of the insulator string and the minimum flashover value required between the conductor and tower.

TABLE 1

Gas Spacing Inches	Kv Flashover Value 1½ x 40 Positive Wave
5	106
6	128
7	141
8	159
9	175
10	190
15	275
20	350
30	505
40	650
50	800
60	945

(1) Report of EEI-NEMA Joint Committee on System Insulation Co-ordination Electrical Engineering, June 1937.

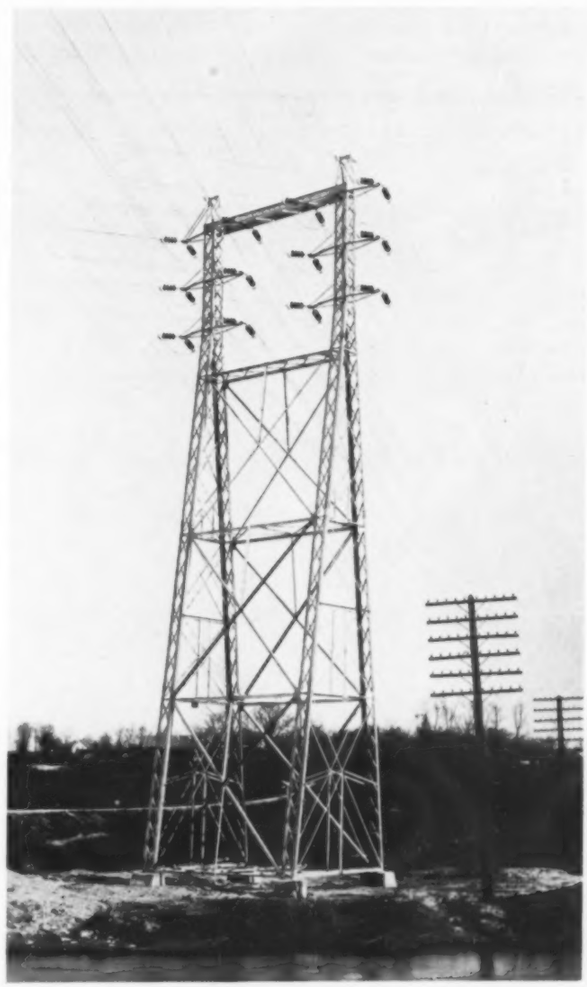
The supporting structures are usually designed to give a factor of safety of from 1½ to 2 over the assumed loading conditions. The loads on the towers consist of the vertical weight of the wires, the transverse load due to the wind force acting against the wires and tower, the transverse load due to angles in the line, the dead load of the tower itself, and the loads in the direction of the line resulting from one or more broken wires. At dead-end points in the line and at railroad crossings, it is necessary to design the structures to resist the unbalanced load which would be produced if all of the wires were broken on one side of the tower.

It is possible to design a transmission line which will be practically immune from trouble were it not for sleet and lightning. Most of the interruptions from sleet occur when the sleet formation drops off from the wire. Unfortunately, this does not happen uniformly. With a vertical configuration of wires, the sleet may drop off of the lower wires first, causing a vertical displacement which will bring the unloaded wires into contact with the loaded ones. A horizontal offset of the wires to secure separation of the conductors under unequal sag conditions should be provided.

Where a single circuit is supported on a structure, greater reliability will be secured by placing all of the wires in the same horizontal plane. Where ground wires are used, they should not be placed directly over a phase wire. Where two or more circuits are carried on the same tower, even if the circuits are of different voltages, it is generally desirable to place all circuits parallel in vertical configuration. This gives a maximum protection in case of ice loads which may cause unequal loadings on wires and will prevent interruptions to more than one circuit in case of a broken conductor. Where parallel circuits are carried on the same structure, it is preferable that they all be of the same size so that they will deflect the same amount under transverse wind conditions. It it is impractical to use the same size wire on all circuits, the transverse movement of the wires should be investigated to assure adequate separation under the assumed worst wind conditions. A further advantage of parallel vertical circuits is the greater ease in maintenance when work is being done on one circuit while the others are energized and to provide greater clearances when it is necessary to make repairs with hot line tools with all circuits energized. Figures 5 and 6 show four parallel circuits of 27 kv and 66 kv respectively on a single tower.

Installation of the Appalachian Electric Power Company at Logan Sripp line, Logan, West Va., using the sidehill extension.

FIGURE 5—Tower located at Benton Harbor, Michigan using four parallel circuits of 27 kv and 66 kv respectively on a single tower.



SPECIAL TOWERS

The location of towers on mill property is fixed primarily by the available sites, and economical heights, base dimensions, and span lengths are not always possible to obtain. In general, however, where normal spacing of towers can be secured but where angles in the line are numerous, it is economical to keep the conductor tension low so as to reduce the angle load on the tower. This will keep the tower weight and the size of footings to a minimum. Where it is necessary to install long spans or where obstructions such as buildings and tracks must be cleared, it is sometimes necessary to install a high strength conductor which

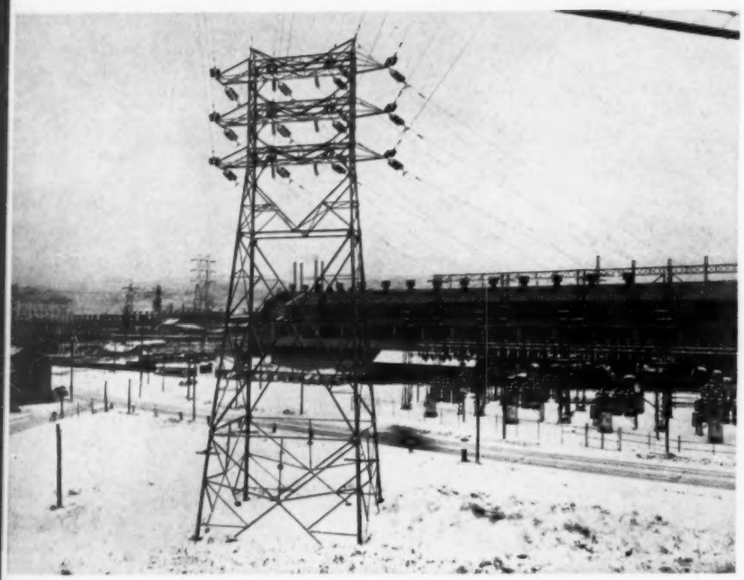
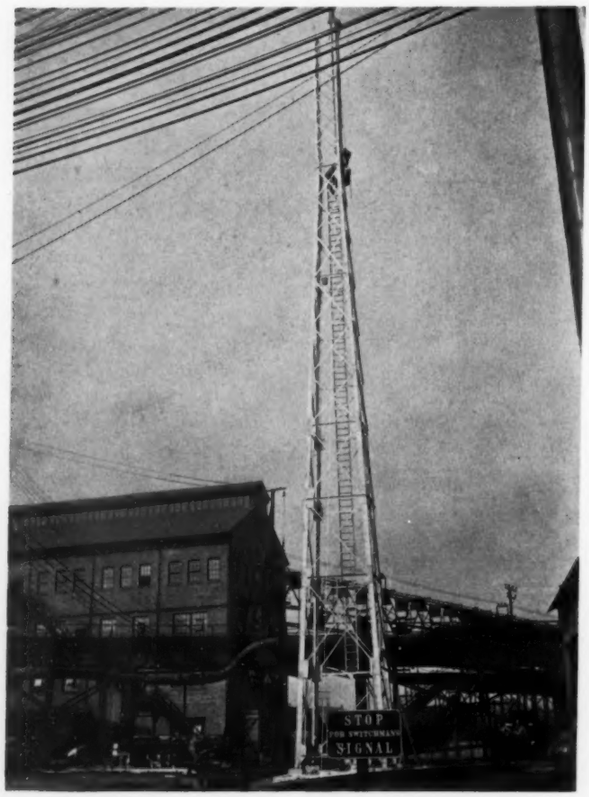


FIGURE 6—Four parallel circuits of 27 kv and 66 kv respectively supplying power to the Wheeling Steel Company at Steubenville, Ohio.

will permit a greater cable tension. Figures 7 to 10 show towers in the vicinity of steel mills where difficult locations have imposed special problems in construction.

FIGURE 7—Note the difficult location of this tower supplying the South Works of Carnegie-Illinois Steel Corp., at Gary, Indiana.



PROTECTION AGAINST LIGHTNING

The major cause of interruptions to service in a large part of the United States is lightning. Since the earliest days of transmission of power by overhead circuits, the problem has been studied and various means of protection have been tried out.

The problem of preventing damage from interruptions due to lightning disturbance may be approached from several angles. A duplicate line or lines may be built on the same or separate rights of way in the hope that during the disturbance on one line, the others may not be affected. A second method of approach is to accept lightning flashovers as unavoidable and provide discharge equipment such as arcing horns or shields rings to protect insulators and to some extent conductors. A third method which is a variation of the preceding one is to provide protective equipment which will discharge lightning currents but which, in addition to protecting the line, will interrupt the lightning current in so short a time that there will be practically no power current follow-up and hence no interruption to service. An example of such a device is the so-called expulsion gap. A fourth method and the one which is most widely attempted on lines particularly of higher voltage is to shield the line from lightning by the installation of overhead ground wires and together with the reduction of tower footing resistance, and through proper insulation levels, to prevent lightning discharges on the line to take place. These four fundamental approaches to the lightning problem will be discussed in the inverse order in which they are given above.

GROUND WIRES

A ground wire to be effective must:

(a) Be located above the line conductors at a height sufficient to intercept the stroke, and to prevent side flashes to the conductors.

(b) Be installed on a structure with low enough tower footing resistance to prevent flashover of the insulators.

(c) Be high enough above the conductors at mid span to prevent flashover to the conductors.

The lighting stroke will normally seek the shortest path from cloud to ground. Through proper location of the ground wire, the termination of the stroke should be on the ground wire or tower top. Various assumptions have been made as to the angle of protection which the ground wire affords. Some assumptions make the angle as small as 15 to 20 degrees and others as high as 75 degrees. A value frequently used is to assume the base of the protected area on either side of the ground wire equal to twice the height from the conductor to the ground wire.

The voltage at the top of the tower struck by lightning may be assumed to equal the product of the tower current and the resistance of the tower to earth. At the same time that the voltage is produced at the tower top, an induced voltage appears on the conductors, the amount of which usually varies between 25 to 35 per cent of that on the tower. The potential across the insulators is therefore the difference in potential between the tower and the conductor. A simplified

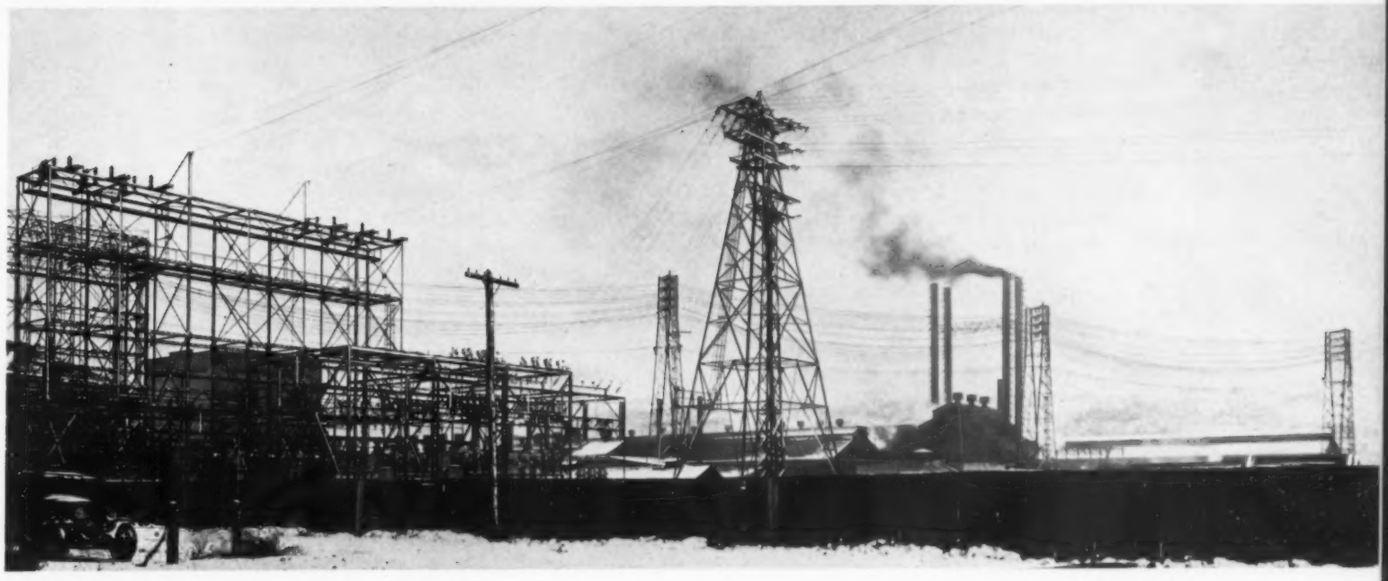


FIGURE 8—View of substation located adjacent to Steubenville Works of Wheeling Steel Corporation.

formula to calculate the tower footing resistance required to prevent flashover is as follows:

$$R = \frac{\text{Permissible voltage across insulator string}}{\text{(Tower surge current) (1—coupling factor)}}$$

This coupling factor equals—

$$\frac{\text{Voltage of line conductor}}{\text{Voltage on ground wire or tower top}}$$

The coupling factor can be calculated for any given location but on medium span and medium voltage lines it may be assumed as 30 per cent. The required tower footing resistance to prevent flashover thus becomes—

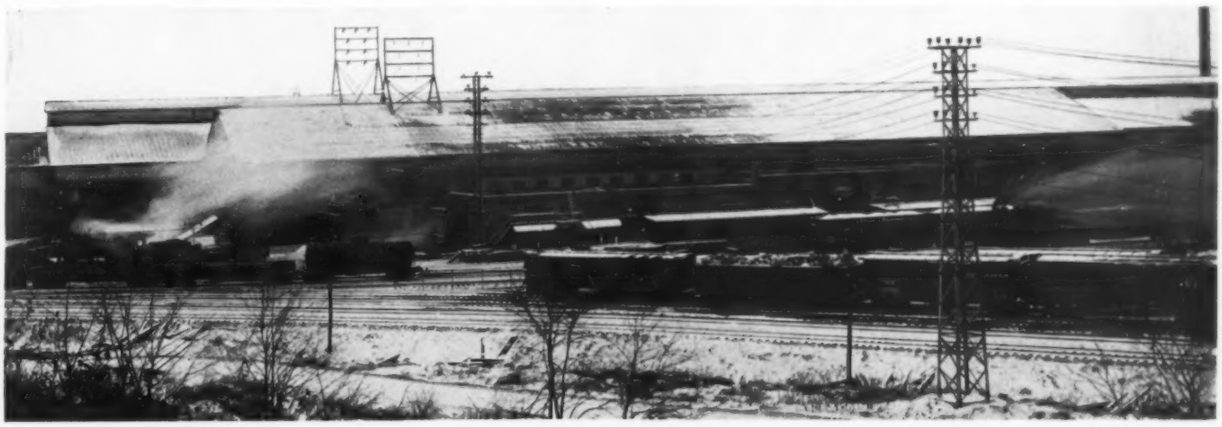
$$R = \frac{\text{Permissible voltage across insulator string}}{\text{70 per cent of tower surge current}}$$

The above formula is an approximate one but will give fairly close results.

For the past four years an instrument has been available to measure currents which actually occur on transmission lines. This tool is the surge-crest ammeter. It consists essentially of a small cobalt magnet approximately 1½ inches long and 0.1 square inch in cross section. The magnet is placed in the magnetic field of the conductor in which the current is to be measured and by measuring the residual magnetism left in the magnet after the passage of the current, the crest value of the current can be determined. Field measurements have now been made on a large number of installations. This device, which has been placed on many towers of the American Gas and Electric Company's system, shows current values as indicated in Figure 11. A value as high as 220,000 amperes has been measured but most of the strokes are much smaller. Eighty per cent. of the strokes are below 30,000 amperes, and 50 per cent below 18,000 amperes.

The wave shape most useful in designing transmission lines is the 1½ x 40 wave in which the crest voltage is reached in 1½ microseconds and the reduction of the tail to half crest value in 40 microseconds from zero

FIGURE 9—These incoming lines supply power to the Canton plant of the Timken Roller Bearing Company



voltage. Table 2 gives impulse flashover characteristics of 10 inch, 5¾ inch spaced units based on this wave.

TABLE 2

Number of Units in String	Flashover kv 1½ x 40 Positive Wave
1	150
2	255
3	355
4	440
5	525
6	610
7	695
8	780
9	860
10	945

INSULATION LEVELS

Transmission line insulation in the past has generally been based on the rated circuit voltage, that is, switching surges have been estimated and the insulation has been made high enough to resist the power surge. Table 3 gives the number of insulators for various line voltages, the 60 cycle flashover values, the ratio of wet flashover value to normal voltage to ground, and the impulse flashover values based on a 1½ x 40 wave. The number of units for the operating voltages given is based on the common practice of a number of large operating companies.

TABLE 3

Line Voltage	No. of 5¾" Units	60 Cycle Wet Flashover Kv	Ratio of Wet Flashover to Normal Voltage to Ground	Impulse Value Kv 1½ x 40 Pos. Wave
34.5 kv	3	145	7.3	355
46.0 kv	4	200	7.5	440
69.0 kv	6	290	7.3	620

This table gives the ratio of wet flashover voltage to normal voltage to ground slightly in excess of 7. It is rare that switching surges will exceed 5 times line to ground voltage. On the basis of 60 cycle surges the value of insulation given in the table seemed liberal.

Let us investigate the insulation, however, for lightning surges by assuming a surge current at the tower top of 40,000 amperes which from Figure 11 will not be exceeded by 90 per cent of the surges. For the 34.5 kv line with three insulators, the impulse flashover value is 355 kv. From the formula previously given, the tower footing resistance

$$R = \frac{355{,}000}{40{,}000 \times .70} = 12.7 \text{ ohms}$$

The corresponding value for a 46 kv line with four units of insulation would be 15.7 ohms and for a 69 kv line with six units 22.2 ohms. For a 33 kv line it will be seen that with three units of insulation, a ground resistance of approximately twelve ohms will be required in order to secure protection from 90 per cent of the expected strokes.

It is evident that in order to make lines lightning resistant, low tower footing resistances must be secured; that is, in the order of ten ohms or less. Some towers are fortunately so located that very low footing resistances may be secured without special means. Others, on the other hand, may have measured resistances of 50 ohms or more. The most economical expedient to attempt in order to lower ground resistance is the driving of ground rods. These rods are generally a minimum of ¾ inch in diameter and 8 feet in length. They may be of copper, Copperweld, or steel, depending upon the corrosive nature of the ground. The conductivity of a rod ground resistance depends very little on its cross sectional area but mainly upon the moisture content of the soil which it reaches. The customary practice where unknown grounding conditions occur is to drive a rod of a length of 8 or 10 feet and measure its resistance by means of a ground ohmer. If one rod does not lower the resistance to a required amount, a second rod is driven spaced 5 or more feet from the first. If it is evident that three rods of this length will not suffice to lower the resistance to a sufficient amount, it is sometimes possible to secure the required resistance by driving long rods up to 50 or more feet in length.

FIGURE 10—Close-up view of part of the installation at the Timken Roller Bearing Company, Canton, Ohio.

In driving long rods it may be expedient to utilize a mechanical driver such as a gasoline hammer.

It may be found impossible to secure low resistance with driven grounds, and in such event a counterpoise seems to be the only solution. Counterpoises consist of wires usually buried in the ground at depths from 18 inches to 3 feet. They are connected to the tower leg and may extend either parallel to the line or in radial directions. Measurements of currents on counterpoises indicate that they should be from 200 to 300 feet in length as a minimum. If the leakage resistance is less than 200 ohms per foot, it may be expedient to install a continuous tower to tower counterpoise.

EXPULSION GAP

Another method of approach to the lightning interruption problem is the expulsion gap. Its function is to discharge the lightning current without allowing the power current to follow the lightning discharge. The gap should have the following characteristics:

(a) It must prevent line insulator flashovers, and therefore it must have a lower impulse breakdown than the line insulation.
(b) It must interrupt successfully any power current that the line may impose.
(c) It must be weather-resistant and reliable.
(d) It must be mounted so as to be readily accessible for inspection and maintenance.

The gap consists essentially of an internal gap placed inside of a fiber tube. The tube, the outline of which is shown in Figure 12, is mounted in series with an external gap. It may be mounted either parallel to an insulator string with one end at tower potential, or underneath an insulator string attached to a special cross-arm or pipe. The former type of mounting is shown in Figure 13, which shows an installation on a 132 kv line. In this case due to the high voltage of the line it is expedient to utilize two tubes each with an internal gap and with an external gap between them. On lower voltage lines a single tube is installed, the external gap extending from the tube to the conductor. On such an installation, a protective sleeve is generally placed on the conductor to prevent burning. When the expulsion gap is mounted below a suspension insulator string, the top of the gap is provided with a curved horn so that the exact external gap between the conductor and the device is maintained during lateral displacement of the insulator string.

For maximum protection expulsion gaps should be installed at every structure on the line and at every insulator string. With this arrangement low tower footing resistances are not necessary. Partial protection can be secured if the gaps are installed at longer intervals but low footing resistances and high flashover values of the insulation on the unprotected structures are necessary.

Installations of expulsion gaps have been made on transmission lines with operating voltages varying from 13.8 kv to 132 kv. Experimental installations have been made also on 220 kv lines. On the 132 kv system of the American Gas and Electric Company over 3,000 expulsion gaps are now in service. Operating records have shown that the gaps are effective in reducing flashover of insulators and in reducing line outages. The life expectancy for tubes of present designs does not equal that for other line equipment but eight to ten years of service can reasonably be anticipated.

No description of the familiar arcing horn will be made. The use of such a device is not generally effective in preventing cascading of the insulator string.

A modification of the arcing horn known as the shield ring is shown in Figure 14. This device consists of metallic rings placed at the line and ground sides of insulator strings. Properly designed shield rings will control the path of the lightning discharge and the power current follow-up so as to prevent cascading of the insulator strings. Their sole function is to prevent flashover damage to the insulators and conductors and, of course, have no effect in reducing line outages.

The design of shield rings must be based on laboratory tests using artificial lightning impulses. The diameter of the rings and their position vary with the different lengths of insulator strings.

The use of shield rings on lines with operating voltages below 220 kv is not customarily practiced today due principally to the fact that the speed of relay operation has been so materially increased that destructive burning of insulators and conductors is not prevalent. Shield rings may, however, find economical application on river crossing structures and other high towers which are particularly susceptible to lightning strokes and where extra precaution must be taken.

The practice of installing duplicate lines on the same right of way has been influenced to a large extent by the desire to avoid total interruptions to service due to lightning disturbances. Frequently a single circuit was able to carry the entire load but the second circuit was depended upon to reduce outages and to permit repairs to be made on the stricken circuit. The average percentage of 2-circuit interruptions on the 132 kv lines

These lines of the Appalachian Power Company run through the heart of the city at Huntington, West Va.

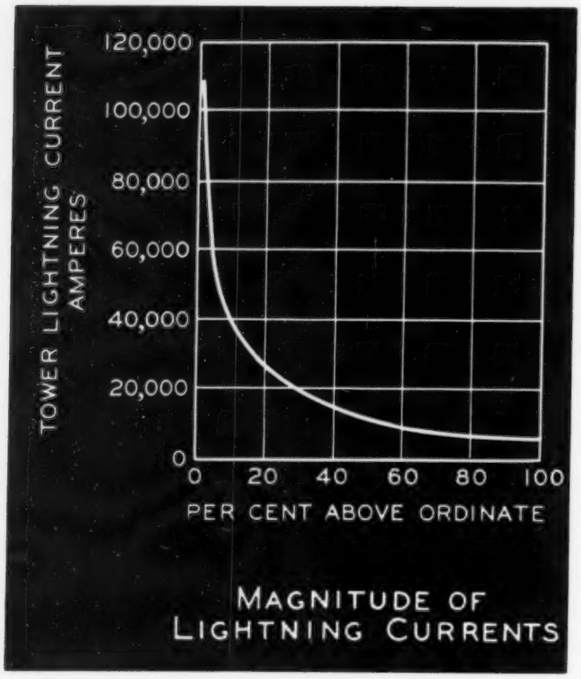
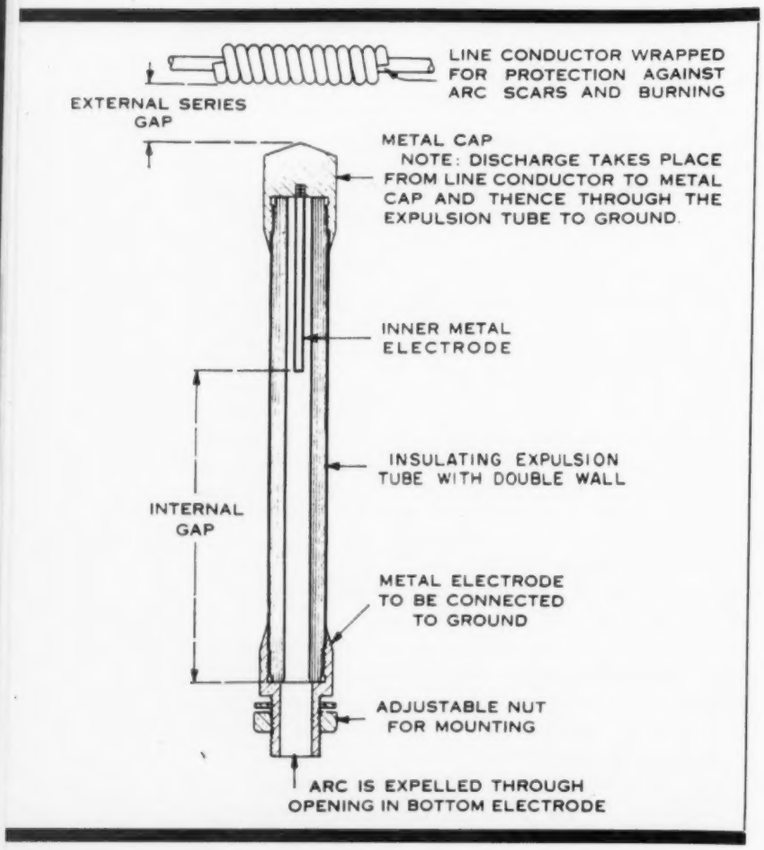


FIGURE 11—Magnitude of lightning currents.

FIGURE 12—This fiber tube is a very intricate part of the expulsion gap, the function of which discharges the lightning current without allowing the power current to follow the lightning discharge.


LINE CONDUCTOR WRAPPED FOR PROTECTION AGAINST ARC SCARS AND BURNING
EXTERNAL SERIES GAP
METAL CAP
NOTE: DISCHARGE TAKES PLACE FROM LINE CONDUCTOR TO METAL CAP AND THENCE THROUGH THE EXPULSION TUBE TO GROUND.
INNER METAL ELECTRODE
INSULATING EXPULSION TUBE WITH DOUBLE WALL
INTERNAL GAP
METAL ELECTRODE TO BE CONNECTED TO GROUND
ADJUSTABLE NUT FOR MOUNTING
ARC IS EXPELLED THROUGH OPENING IN BOTTOM ELECTRODE

of the American Gas and Electric Company covering a period of eight years was 25 per cent. With an increased knowledge of the lightning problem and of the remedial measures which may be taken to prevent outages, it is becoming decreasingly necessary to build 2-circuit lines as a means of reducing outages due to lightning.

When two or more circuits between the same source of supply and terminal are built on separate routes, there is an increase in the reliability of service, particularly if the lines are separated by a distance of a mile or more. The cost, however, of obtaining and maintaining two separate rights of way and the high cost of building two lines makes the solution of the interruption problem decidedly uneconomical.

MAINTENANCE OF LINES

The amount of maintenance repairs required on a line will depend to a large extent on the selection of materials and the care taken with the initial construction. Some specific details which affect maintenance are given below.

Where lines extend through timbered areas, it is desirable to clear the timber and brush for the full width of the right of way. This may be as wide as 100 feet or more. Timber should be cut to log lengths and removed or placed at the edge of the right of way. Brush should be placed in piles and burned. If it is left on the right of way, it will rot and encourage future growth. Trees outside of the right of way which are located so that they could reach the conductors in falling must be cut. On long spans in hilly country, the side-swing of the cables under transverse wind conditions must be calculated. All trees within the range of the wires must be cut sometimes at distances as great as 300 feet or more from the edge of the right of way.

The customary type of tower anchor is the so-called earth anchor in which the leg angle attaches to galvanized steel members buried in the ground. In ordinary soil the life of the embedded steel will equal that of the superstructure. If, however, the earth contains corrosive compounds such as ashes, slag, or coal, it is necessary to protect the anchor steel against corrosion. Protection may be obtained by encasing the steel in concrete or by applying a bitumastic or asphaltic paint.

Vibration of tower members tends to loosen bolted connections. Maintenance can be reduced by placing lock washers or lock nuts on all bolts or by prick-punching the threads of the bolt just beyond the nut.

All types of cables whether of steel, copper, aluminum, or composite materials are subject to vibration. This may be severe enough to cause failure of the wire if care is not taken in the choice of clamps and method of attachment to the tower. Fixed attachments, even of the ground wires, should be avoided. At suspension points clamps should be used which, while firmly gripping the cable, will permit the maximum flexibility of attachment.

It is customary, when steel reinforced aluminum cable is used, to provide extra protection at the suspension clamps by wrapping the cable with an extra layer of wire called armor rods or by installing devices on the

cable which will dampen the vibration. The latter method is preferable. Devices such as the Stockbridge damper are effective in practically suppressing vibration. The device consists of flexibly attached weights which are installed on the conductors a few feet beyond the suspension clamps.

In the vicinity of steel plants, it is sometimes necessary to clean off deposits on the insulators. Such deposits ordinarily do not reduce the dry flashover value of the insulator strings nor do they seem to affect the lightning flashover values. They do, however, seriously reduce the wet flashover values of the insulators and sometimes cause radio interference as well. If deposits can not be cleaned by means of water, hydrochloric acid may be used. Care should be taken, however, to thoroughly wash the acid off of the insulator so that there will be no corrosion of the metallic parts.

All of the component parts of a transmission line should be considered as permanent equipment. It may be expected that the lines will have a life of twenty years or more. All lines, however, require maintenance attention. An inspection should be made after every lightning storm in which an outage has occurred to locate any possible damage to the conductors, insulators, hardware, and towers. In addition to such intermittent inspections, a more careful and thorough inspection should be made at least once a year. During this inspection all towers should be climbed and a close-up view obtained of the insulators and cables. The tightness of bolts should be investigated and all rust spots should be painted. After a line has been in service for a number of years, it is well to check possible vibration damage to the conductors at the suspension clamps.

On most lines it is difficult to obtain clearance so that they may be deenergized for maintenance repairs. The use, therefore, of equipment which will permit such repairs to be made with the circuits energized is becoming increasingly necessary. Hot line tools have now been developed to such a degree of perfection that almost all minor repairs such as changing insulators and hardware can be made. It is necessary, however, that the crew of men which performs this work be thoroughly trained so that they will do the work safely. Operating records have proved that hot line work can be performed just as safely as work on de-energized circuits.

FIGURE 13—Expulsion gap mounted on a 132 kv line and using two tubes each with an internal gap and with an external gap between them.

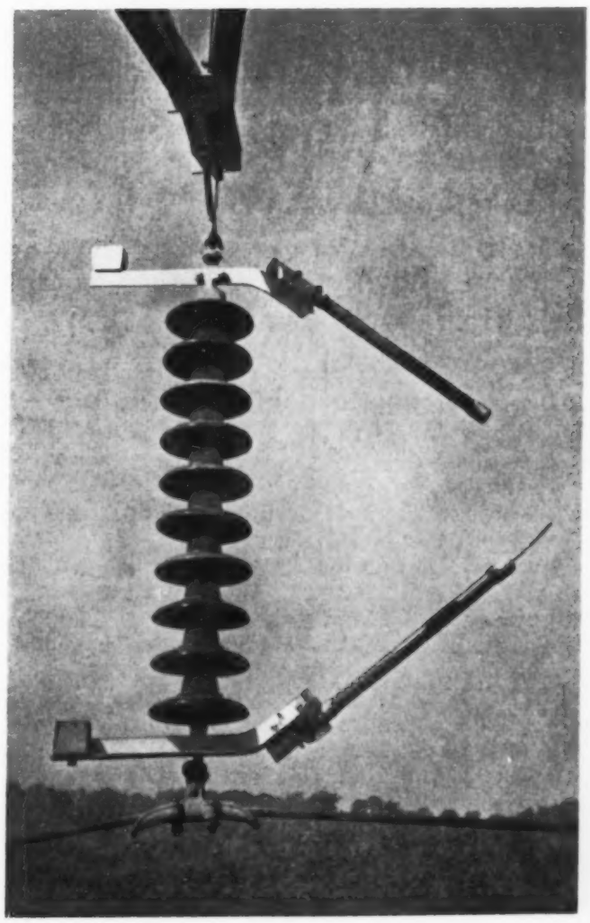


FIGURE 14—This type of shield ring will control the path of the lightning discharge and the power current follow-up so as to prevent cascading of the insulator strings.

DISCUSSION

PRESENTED BY:

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C. O. FRANKLIN, Assistant Superintendent, Electrical Department, Carnegie-Illinois Steel Corporation, Homestead, Pennsylvania.

J. J. BOOTH: I want to congratulate our Pittsburgh Section on having a man of the type of Mr. Peterson to deliver the paper we have heard this evening, and we compliment Mr. Peterson on the paper he has given. He has covered in an excellent manner many of the problems that we, who are dealing with this particular type of work at the present time, can well use. I know of several questions which have been asked during the last year and a half which have been answered very conclusively in Mr. Peterson's paper. There are one or two points on which I would like to have Mr. Peterson's opinion.

1. In establishing grounds, do you pay any particular attention to segregating your ground for lightning disturbance from station ground?
2. Do you bring your ground circuit from your rods above the ground, or do you attach them to the tower below the surface of the ground?
3. In the event you are grounding disconnect switches on a tower, half way or more up the tower, would you run a 4/0 or 300,000 CM copper wire up to your connection, or would you depend entirely on the steel tower for grounding?

E. C. MARSHALL: Mr. Peterson's paper has been read with keen interest and even though his paper implies that the troublesome factors are for high voltage lines, the causes cited, namely, sleet and lightning are also objectionable on low voltage lines.

Due to the prevailing dirt conditions in steel mills, where in particular, much of the dust is both magnetic and conductive, some additional overhead line troubles can be anticipated.

As the author has so ably brought out, many of the towers must be heavily constructed due to the infrequency of tangential spans, thus resulting in a large number of strain towers. It is conceivable that the increased cost of higher towers to avoid mill buildings and other obstructions, would probably be as expensive construction as the use of strain towers, particularly in congested areas.

For longer routes however, the higher tower may have some advantages.

Should it be intended to use the same towers for carrying the heavy lower voltage conductors between the various mill buildings, the tower construction becomes more involved.

On the other hand if the larger lower voltage cables are run in under ground ducts then it seems pertinent to inquire why not run the high voltage lines underground also.

The advantages would not only be the greater reliability of service, but greater safety, comparative ease of maintenance and possibly at no greater cost than the overhead system combined with some underground duct lines.

However, for interplant connections, where long runs are involved, the conventional overhead line may prove most economical.

I would appreciate the author's comments as to whether or not he has made and can submit any comparative data on the two systems for steel mill service.

C. T. SINCLAIR: Mr. Peterson has given us a very complete summary of the principles of transmission line design that are today accepted as fundamental. Most of these principles apply to all transmission line design, but as Mr. Peterson has pointed out, there are a number of features that are peculiar to steel mill supply. Under the most favorable conditions, the normal difficulties of line design are accentuated.

It wasn't so many years ago that many of us accepted transmission line outages from lightning as inevitable. Engineers of the manufacturing and operating companies began collecting field data and corelating this with laboratory tests, and this resulted in a better concept of just what was happening. A more general use of the surge generator, the cathode ray oscillograph and the surge crest ammeter added tremendously to our store of information. The work of Fortescue, Peek and others, including the engineers of Mr. Peterson's Company, resulted in transmission lines that are very largely free from lightning.

There was a time, not so many years back, when the ground wire was in ill repute in many places. Today, the ground wire is one of our most effective means of adequately protecting our lines. The difficulties with ground wires in the past were largely mechanical troubles and improper application, and these

facts are well known and generally accepted today.

It is a fact that our knowledge is far from complete. For example, shielding assumptions generally vary from 15 degrees to 75 degrees as mentioned in the paper. Data is still being collected on the magnitude of the current in lightning strokes, and Figure 1 of the paper shows the results of the data collected by Mr. Peterson's Company.

The expulsion gap appears to have real possibilities as a means of preventing line outages from lightning. While some mechanical difficulties were experienced in operation in the earlier designs, these difficulties have been largely eliminated, and the operating performance has been very gratifying. An inherent characteristic of the gap is that during each operation a small amount of the fiber in the tube is worn away, and this errosion gradually enlarges the tube diameter until the point is reached where it will no longer function satisfactorily. The tube must then be replaced.

It is therefore apparent that the tube life is limited, and sooner or later it must be replaced. This life must be measured in number of operations rather than in years. From this viewpoint a tube that may be called upon to discharge once every few years may have a life equal to that of the line, while a tube that discharges many times each season may have to be replaced in a few years. This does present a problem in operation, requiring a reasonably careful check on the condition of the tube.

Other methods of lightning protection suggested by Mr. Peterson,—the ground wire, counterpoise, higher insulation levels, arcing horns and shield rings,—are all methods that are relatively as permanent as the line itself.

To those of you who are directly interested in the problem of lightning protection of transmission lines, I would refer you to the American Institute of Electrical Engineers Lightning Reference Book, published in July, 1937, which contains outstanding articles and papers from Electric Journal, General Electric Review, Journal of the Franklin Institute, Electrical World, and the American Institute of Electrical Engineers. This book was prepared under the direction of one of Mr. Peterson's business associates, Mr. Sporn. I have personally found this book extremely useful and I recommend it for your use.

WRAY DUDLEY: Steel mill engineers are not called upon very frequently to build transmission lines, consequently they normally have but little opportunity to acquire first hand knowledge of what constitutes a first class design. In the paper to which we have just listened, the author has presented in a very clear and instructive manner the essential requirements which should first be established before the plans can proceed very far. In exclusing unnecessary detail and theories, and in presenting conclusions which evidently are based upon wide practical experience and observation, this paper simplifies the subject materially and should prove to be particularly useful to steel mill engineers who may become responsible for the construction or operation of a high voltage transmission line. I feel that the Association is to be congratulated upon securing this paper for publication and the sincere thanks of the membership should be extended to Mr. Peterson.

The transmission lines with which steel mill engineers are usually directly concerned are generally those within the confines of a single plant or those which form a connecting link between related plants within a limited area. In practically every case they are of relatively short length and while their construction may represent a very substantial sum, it is usually but a small percentage of the total investment cost of the operations which it serves. However, if the operations are largely dependent upon the transmission line for continuity of production, a power interruption will impose a heavy and immediate loss. For instance, in a steel plant having a monthly payroll of $1,000,000.00, a power interruption can easily entail an hourly direct producing labor loss ranging from $500.00 to $1500.00, depending upon the extent of operations affected. In addition to the labor loss there will be other serious developments, such as damage to product or equipment, interruptions to schedule, and possibility of injuries to personnel.

Because the steel mill transmission line is usually of short length, with its cost representing a relatively minor item in the total plant investment, and because the adverse effects of a power interruption to mill operations are so directly and immediately evident to all concerned, the steel mill engineer will usually receive every reasonable encouragement to design and construct his own transmission line in such manner as will give maximum insurance against power interruption due to any fault or omission in its design. It is pleasing, therefore, to find that the safety factors, insulation levels and protective devices, suggested in Mr. Peterson's paper, are conservative in character and will lend support to the naturally cautious attitude of the steel mill engineer.

In his reference to the matter of calculating conductor strength the author refers to a wind force of 8 pounds per linear foot acting on a wire covered with ½ in. radial thickness of ice. Possibly this should read a wind load of 8 lbs. per square foot which would correspond to an actual wind velocity of some 57 M.P.H. It would be helpful if the author could advise us if this is the maximum wind velocity in exposed locations for which present day lines and towers are being designed.

Concerning the matter of tower footing resistance, I would like to ask the author if he has had any success with driven grounds in high level districts with terrain similar to the hills which enclose the valleys in the Pittsburgh District. The formation usually consists of say 8 to 10 feet of clay soil above a bed of shale, which in turn rests upon solid rock. In this formation, apparently, it would be practically impossible to drive a rod more than 8 or 10 feet. In areas of this character is it possible to maintain a ground resistance within the recommended 10 ohms or less with any reasonable degree of certainty during the dry summer and fall seasons?

JAMES FARRINGTON: I would like to ask Mr. Peterson if he can give an explanation for cracks in concrete at base of towers?

Is the trouble that may be caused by melting ice serious on spans of 500 feet or less?

Should nature of the surrounding air be considered in selecting insulators when the insulators can not be cleaned more than twice a year?

Would you consider expulsion gaps applied at each insulator too expensive for the protection afforded? What intensity of vibration is necessary to warrant installation of suspension clamps?

We believe two separate circuits desirable at times as it is not possible to get at the line when trouble develops. Disconnect switches, switch houses, bushings, and pot heads should be tested frequently to avoid flashover or grounds due to lightning. Ground lines to be of heavy construction to withstand mechanical force of flying sheet iron on stack guys. Factor of safety too low for steel mill service.

A. C. MONTEITH: Mr. Peterson is to be congratulated on the clear, concise manner in which he has presented the main factors on this very broad and involved subject. Through the good work of his and other operating companies much has been learned on this subject and a review such as presented is very useful in a developing art. It is recognized that in such a digest it is impossible to take all factors into account; however, I would like to comment on three points.

Several different ideas on the location of the ground wires in the shielding of transmission lines have been cited. Observations incline us to recommend the 15 to 20 degrees between a perpendicular line through the ground wires and a line joining the ground wire and the outer conductor. It is our belief that there is a probability factor with respect to the shielding obtained with different locations of ground wires. The use of 60 or 75 degrees as mentioned will give some shielding but it will not be as complete as the use of the smaller angle. More data is needed on this point but some observations during storms and also some operating experience on lines emphasizes the desirability of the smaller angles.

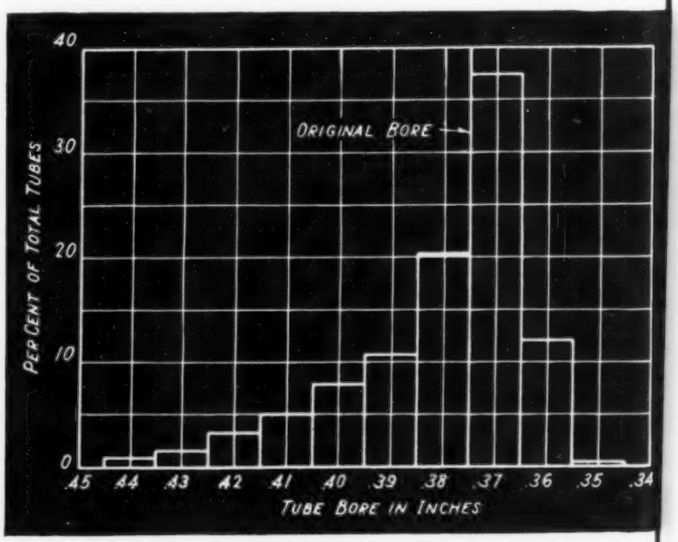
I am told by an eye witness that a stroke terminated on the Bessemer tracks at East Pittsburgh at a point fairly close to some buildings. The Bessemer tracks at this location are at the base of a very steep hill and are well within the 60 degree angle. In another case an eye witness tells of seeing a stroke terminate half way up the side of the spire of a church at the end of Wall Street, New York. I have also been told that strokes have terminated at the base of the mooring mast on the Empire State Building.

One operating company with four years experience on approximately 100 miles of double circuit line had an average of 3.9 outages per 100 miles per year with a single ground wire. The angle from a perpendicular through the ground wire was approximately 30 degree to the upper conductor for one circuit and 60 degree to the upper conductor of the other circuit. In the same general area and during the same seasons with approximately the same construction and soil conditions the same operating company had 1.27 outages per 100 miles per year on 150 miles of line when two ground wires were used with a maximum angle of 30 degrees. Again in the same general area and over a period of seven years another operating company had 0.3 outages per 100 miles per year on 45 miles of double circuit line, with the ground wires located vertically over the outside conductor but conditions and spacings otherwise approximately the same as the first operating company. This data is meager and therefore cannot be used as conclusive but it does indicate that there is a probability factor in the shielding depending on the location of the ground wire.

A formula is included for arriving at the ground resistance for a given probability of outage on the line. This formula is no doubt satisfactory for estimating purposes on medium voltage lines but in arriving at a final design it is believed that span length and tower surge impedance should be considered, otherwise the calculated resistance might be misleading. Curves were published in the February 1934 Electric Journal in an article "Transmission Line Design Estimates Simplified". These curves prepared by the writer take these factors into account for a one microsecond front on the wave.

In discussing the line protector tubes, estimates of eight to ten years of service are given. The life of a protector tube will depend upon the number of strokes to be handled and the power current that follows. A tube on a high voltage line should last longer than one on a low voltage circuit. We have just secured some interesting information on de-ion protector tubes that have been in service five years on the Interstate Power Company line between Clinton and Dubuque, Iowa. In six years previous to the installation of the tubes they had 277 outages on 55 miles of 66 kv. line. This gives some indication of the severity of lightning in this territory. At the time the tubes were installed the bore was 0.375 in. A limit of 0.45 in. was set as a tube that should still be satisfactory for operation on this line. Measurements have just been made on 1050 tubes and in the five years of operation no tubes have reached this bore and the percentage that even approached this is very small. Figure I shows a detailed analysis of how the bore has increased. It shows one per cent have increased to 0.44 in. and only five per

FIGURE 1



cent have increased to 0.41 in. It is therefore seen that the estimate of eight to ten years is no doubt close for a few tubes on the line but the average life expectancy should be considerably longer.

E. L. PETERSON: Answering Mr. Booth's question with regard to segregating station ground from the tower ground, it has been our practice to make this ground continuous; in other words, extend the ground wire directly into the substation structure and tie that ground wire definitely to the station ground.

With regard to the location of attachment of ground to the tower, it is preferable I believe to connect to the tower below the ground line mainly from the standpoint of possible theft of the cable connecting the ground rod to the tower. We had a 66 kv. line from which someone removed most of the connection cable rendering the ground ineffective. Possibly $5.00 worth of material was collected on all the grounds.

With regard to grounding a disconnect switch on the tower, our practice has been to rely on the tower itself to make the ground connection between the switch and ground.

Mr. Marshall raises the question as to the possible economy of using underground cables instead of long span strain towers, our exprience has been that in most cases the cost of overhead circuits is less than the use of underground cables; and I believe that reliability will be greater. It is true that around steel mills there are many factors which affect reliability, such as dirt on insulator strings, and possibly flying objects which may damage the conductor. But in spite of this with overhead lines, in case of trouble you can see where it occurs, and repairs can be made within a short time.

Mr. Sinclair discussed the possible wearing out of tubes. To date after having a large number of tubes installed for five or six years, this has been the least of our worries. We have had no trouble to date from excessive increase of the bore of the tubes. We have had cases, however, where tubes warped out of shape and where the coating became deteriorated due to the action of sunlight; also some cases of flashovers over the outside of the tubes. However, we feel that most of this trouble was due to lack of design knowledge, and we can expect almost perfect performance on future tubes. I do not believe, however, we will ever obtain long life of tubes until a more permanent coating can be applied to the outside of the tubes.

Mr. Dudley has discussed continuity of service and loss by damage and interruptions in case of outage. He also mentioned an error in the paper wherein it gives a wind load of 8 pounds per "lineal foot", which should have read square foot. In regard to a wind load of 8 pounds, this means a wind velocity somewhere in the neighborhood of 60 miles per hour. It has been our experience over a period of twenty years that if a line is designed for an 8-pound wind acting on cables covered with ½ inch ice it will withstand any condition that may reasonably be expected to occur.

With regard to our experience obtained on low ground resistance with driven grounds in the Pittsburgh area, we do not operate in the immediate vicinity, but judging from territory in Virginia and West Virginia, it is difficult to obtain less than 20 ohms, and it may be necessary to install counterpoises to lower ground resistance.

With regard to Mr. Farrington's question as to cracks appearing at the base of the tower, and whether this was due to moisture, I assume this was a case of using concrete anchors, in which case it may have been due to moisture getting in between the concrete and steel and thus causing trouble due to rust or freezing. We have heard of cases of lightning damage to concrete where there was no external ground around the anchor, but have had no records of lightning trouble where external grounds were used.

With regard to spans less than 500 feet and ice trouble that might be expected on such lines, it is true that most of the sleet outages occur on long span lines. With a span of 500 feet, we should, however, take into account the possibility of the conductors getting together to the extent of providing a horizontal offset between the middle crossarm and the top and bottom crossarms.

With regard to Mr. Farrington's question whether insulation should be increased in the vicinity of steel mills on account of the nature of the soot and dirt, I do not believe that in most cases it would be necessary to increase the insulation. It should be possible to keep insulators clean by means of hot line tools. If necessary the insulators can be lowered to the ground, cleaned, and then replaced without interrupting service. If too high insulation is used, there is a possibility that surges will be carried into the substation for which the station equipment is not designed.

With regard to expulsion gaps on each insulator string, I believe it will be found economical to install gaps on each string, particularly in the vicinity of steel mills.

D. I. BOHN: What has been your experience with expulsion gaps on 13.2 and 6.6 kv lines?

E. L. PETERSON: We had no installations on such a low voltage. Our lowest has been on 132 kva.

MERRILL DEMERIT: The Consolidated Gas Electric Light & Power Company of Baltimore have tubes on 13.2 kv to a considerable extent and have kept careful record of results. The records are given in the minutes of the T. & D. Committee of a Edison Electrical Institute meeting held during the last year. Mr. L. G. Smith of the Consolidated Gas Electric Light and Power Company at Baltimore probably would be glad to give you any information available.

G. H. CRISS: If I understood Mr. Peterson's answer correctly on the grounding of substations, the grounds to the tower and substation were presumably on the same line.

E. L. PETERSON: Yes.

G. H. GRISS: Have you ever had any returns through the substation?

E. L. PETERSON: We would consider that impossible. The down lead is carried right into the station ground.

G. H. CRISS: At the Cambria Steel Plant, probably

twenty years ago at a substation in the mountains there was trouble of that kind every time there was a severe electrical storm. The line was protected with gap arresters about six or eight to the mile. This number was increased in addition to putting electrolytic arresters at each end of the line and the line was protected with the best known method at that time. However, there was still trouble, the arresters indicated that they were properly performing their function but finally a surge got through and put the machine out of business in the substation. Upon thoroughly checking it was found that every indication showed that the surge had been discharged to ground and through ground to substation apparatus ground and punctured the machine. It was decided at that time that the ground of the line protection and the ground of the substation apparatus were too close together and the grounds were farther separated and seemingly eliminated the difficulty.

E. L. PETERSON: I wonder if ground resistance was known?

G. H. CRISS: We checked it from every angle and the only way we got protection was to segregate those grounds from any backflow of static through the ground.

E. L. PETERSON: The common practice is to obtain very low ground resistance, and in most cases we can obtain 5 ohms or less.

A. S. FINDLAY: We have a three phase 6600 volt line that passes at right angles, high overhead above a soaking pit building, gas producer and 43 in. buildings which give off considerable heat. We have had numerous direct hits of lightning at this point and are anticipating the installing of parallel ground lines to this three phase circuit.

Have you any available data relative to heat ionization and its inviting influence in affording a path to lightning.

E. L. PETERSON: It seems possible that heat ionization could have an effect on the path of lightning.

JAMES FARRINGTON: We have lines directly over stacks that were put in after the lines were put there, and we put a heat shield over the stack to keep the heat from coming directly over the wire, say within 8 feet of the wire. The heat rises between the two circuits and we have had no trouble from lightning in five years service.

C. O. FRANKLIN: I would like to get Mr. Peterson's opinion as to the minimum distance a 6.6 kv line should be located below a 44 kv line on the same structure, if it is impractical to locate them at the same elevation.

E. L. PETERSON: I would say about 7 feet would be the proper distance on spans up to 300 feet.

T. J. Ess JOINS STAFF *of A. I. & S. E.*

T. J. ESS, Combustion Engineer, Republic Steel Corporation, Massillon, Ohio, has resigned this position to become affiliated with the Association of Iron and Steel Engineers, at Pittsburgh, Pennsylvania. Mr. Ess' chief duties with the Association will be the sponsoring of new editorial projects for the "IRON AND STEEL ENGINEER", which is published by the society. Mr. Ess is intimately acquainted with Association activities, having acted on various committees for many years, recently serving as Chairman of the Cleveland Section, and has been a steady contributor of special articles to the "IRON AND STEEL ENGINEER" during the past five years. Mr. Ess was graduated from the Carnegie Institute of Technology in 1922, receiving the degree of mechanical engineer. His first steel mill affiliation was with the Central Steel Company, Massillon, Ohio, where he spent several years in the maintenance department, later being made the assistant steam engineer. Since the merger of the United Alloy Steel Corporation to form the Central Alloy Steel Corporation, and later Republic Steel Corporation, Mr. Ess has been the Combustion Engineer at the Massillon Plant.

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THE *Chemistry*

By GEORGE F. BOWERS

Standard Oil Co. of Indiana

CHICAGO, ILLINOIS

Presented before the A. I. & S. E. Annual Spring Conference, Baltimore, Md., April 28 - 29, 1938

▲ AT first thought it would appear that there would be no justification for a paper on the subject "The Chemistry of Lubrication". This thought is only natural, since the application of chemistry to lubrication has been increasing so gradually—one might almost say subtly—that it has hardly been noticed. This change has been similar to the addition of one inch to a ten foot rod; the addition is hardly discernible. However, as inch after inch is added at regular intervals, the time comes when the additions are not only noticed but are strikingly apparent. So with chemistry in lubrication. Its application was so gradual that it was accepted as a matter of course. Now, however, the chemistry of lubrication is not only a necessity but a boon to industry. It is only with a knowledge of what can happen that such happenings can be aided or prevented and the application of chemistry to lubrication furnishes part of this knowledge. The expression "part of this knowledge" is used advisedly since chemistry alone does not solve problems. It is only by the application of all knowledge, physical, mechanical, that the efficiency of lubrication is increased.

This subject is too large to be covered completely and entirely in this paper so only a few of the more important phases, particularly those encountered in the steel mills will be discussed.

The chemical structure of the molecules of a petroleum lubricant is known to be complex but relatively speaking the exact structure, with but few exceptions, is unknown. This condition obviously makes the problem of forecasting performance more difficult so improvement comes only as a result of research and experience.

Circulating oils have been in use for many years and each year has seen circulating systems applied to additional installations and to different types of installations. Furthermore the demands made on the oils in such systems are becoming increasingly severe. The problem is no longer the simple one of selecting a usable viscosity and only by the application of chemistry has it been possible to make available products better able to meet the increasingly exacting demands. There are certain requirements circulating oils must meet and when expressed in terms of characteristics of the oil, they are:

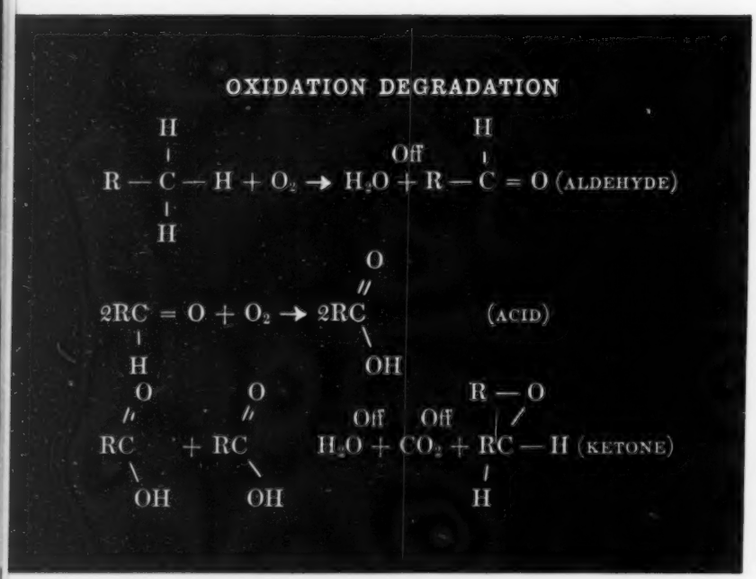
1. The correct viscosity to furnish adequate lubrication without excessive fluid friction.
2. A pour test sufficiently low to insure fluidity at any temperature that may be encountered in the installation.
3. A good demulsibility to permit removal of water which gets into any system.
4. A high stability to insure resistance to oxidation and sludging.

It is particularly in demulsibility and stability characteristics that chemistry is involved. Unquestionably, other things being equal, the less polar (active) the compounds, the better the demulsibility. In other words the more highly a petroleum oil is refined the more nearly a saturated compound it becomes. It therefore is relatively stable (less polar) and more resistant to the attack of air and water. Since the demulsibility of the oil in service is affected by rust, dust, metallic particles, etc., and because of the difficulties involved in the test, too much confidence cannot be put in the results. Nevertheless, theoretically, when the demulsibility remains high it indicates a minimum of oxidation.

The word "stability" has been used so loosely that it may not always convey the desired meaning. In this discussion it will be used to cover resistance to deterioration, oxidation and sludging of an oil in service. In a circulating oil this characteristic is of prime importance and cannot be stressed too strongly.

In order to understand what happens it is necessary to examine the chemistry involved. In the presence

FIGURE 1



try of LUBRICATION

of heat Figure 1 represents a simple illustration of oxidation degradation.

Ketones are unstable and under certain conditions will oxidize further and this or a similar reaction occurs with petroleum oils.

Figure 2 is an illustration of a typical example of oxidation of a branch chain petroleum product.

This oxidation results in a complex branch chain high molecular weight oxygenated compound. With oxygen (air) and heat this compound continues to break down in the same manner until sludges or even coke results. Being a branch chain there are that many more points for this reaction to occur, hence refinery treatment to give as nearly as possible saturated straight chain hydrocarbons minimizes the rapidity and amount of oxidation. The amount of oxidized oil in any oil in a circulating system is one important measure of the quality of the oil. The amount can be determined since oxidized oil is essentially insoluble in naphtha (Hexane) but soluble in chloroform. Circulating oils therefore should be checked regularly to determine the amount of oxidized oil present. (The chloroform soluble portion of the naphtha insoluble material in the oil.) In addition to checking the amount of oxidized oil the neutralization number must also be determined since as the oil oxidizes to acidity this test will show the change.

The actual oil deterioration cycle in a circulating system probably would be about as follows. Unsaturated compounds in the presence of heat and air oxidize to form sludges and acids. The acids in turn react with metals to form metallic soaps. These soaps and sludges may deposit in the system and restrict the flow of oil thus causing an increase in temperature. They also cause an increase in viscosity and therefore more fluid friction so there is an increase in temperature from this source. It is extremely significant that all changes result in an increase in temperature because the rate of oxidation is influenced tremendously by temperature. As a matter of fact the rate of oxidation doubles with about every 20 degrees F. rise in temperature. The rise in temperature due to oxidation causes more rapid oxidation and a further rise in temperature and so a vicious cycle results which keeps on and on until the oil is no longer fit for use.

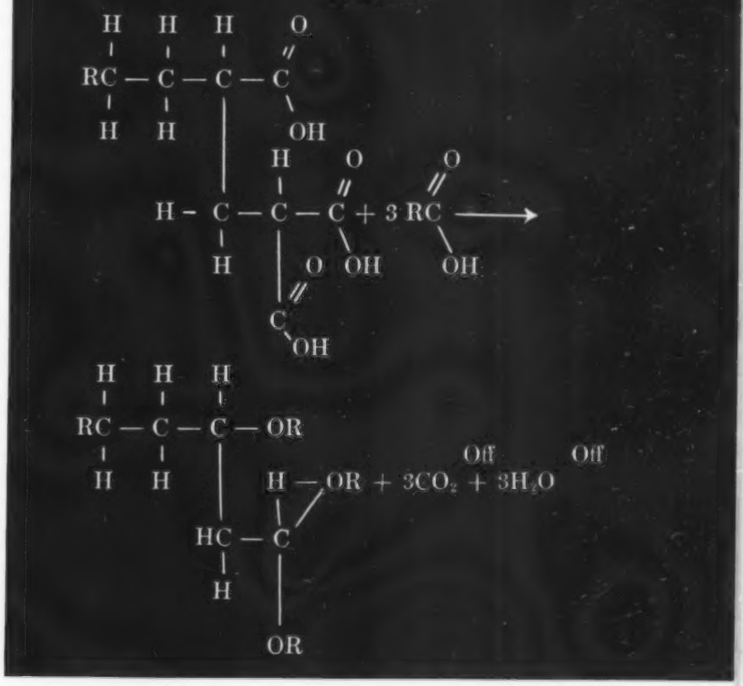
An excellent example of actual changes in an oil is given in the following illustration. Three motors and gear sets were filled with exactly the same oil, viscosity 325 S.U.V. at 100 degrees F. and operated under the same load conditions; the ambient temperature, although controlled, was different in each instance. The results were as follows:

Unit No.	1	2	3
Ambient Temp.	120	125	130
Oil Temperature	163	172	184
Case Temperature	146	153	159
Hours Operation	1240	1520	1360
Oil Vis. S.U.V. @ 100	327	484	500
Total Solids, %	0.51	1.52	1.7
Oxidized Oil, %	0.02	1.45	1.5
The deposit from each case was:			
Total Solids, %	7.9	14.9	22.1
Oxidized Oil, %	0.25	12.3	19.6
Ash, %	6.0	2.3	2.4

Although there was only a relatively small difference in the ambient temperature (10 degrees F.) the oxida-

FIGURE 2

OXIDATION OF BRANCH CHAIN PETROLEUM PRODUCT



tion deterioration cycle did operate so effectively there was a tremendous difference in the oil viscosity, the amount of oxidized oil, and the amount of solids which had formed. There was some deposit in every unit but the amount varied. The deposit was the direct result of oxidation and in unit 3, where there was the most oxidation, there was the most deposit. The solution to this problem was the use of a very highly refined oil which was very resistant to oxidation.

Obviously, as has been pointed out, the more resistant it is to oxidation the longer an oil can be expected to last. The following is a typical illustration of an oil with good stability:

Length of Service	Vis. @ 100° F.	Neut. No.	Naphtha Insoluble	Chloroform Soluble	Ash
1 Month	2037	0.05	....	....	.....
12 Months	2051	0.19	0.02	0.01	0.005

This oil is in a Morgoil system in a hot strip mill and, if the same precautions of removing dirt and water are continued, can be expected to give years of satisfactory service.

It has been pointed out that stable circulating oils are secured by proper and complete refining processes. However, in addition to the refining process, addition agents may be used. Addition agents are of many types and are not used to replace refining but, as the name implies, in addition to it. One class of addition agents are known as inhibitors. Materials which tend to prevent the reaction of oxygen on the product are inhibitors. Unfortunately most inhibitors are water soluble and therefore are not usable because water to some extent is so frequently encountered. Most are polar and themselves unstable in the presence of heat and therefore will not give continuous effectiveness. There are however, inhibitors which can be used in certain oils for specific types of work which give excellent results. The problem therefore is first to secure an oil which has been refined to have the proper characteristics and then to select an inhibitor that is effective with the oil to be used and which will perform its function in the case under consideration.

The lubrication of a turbine is a typical example of the use of low viscosity circulating oil. Most turbine oils are highly refined products with good stability and can be expected to give a few years service before they oxidize to the point that makes them unfit for service. They do oxidize and sludge however, and even with the best purification systems become unfit for service. This deterioration is definitely a chemical reaction and can be eliminated. Very elaborate and complete refining processes will remove the sludge forming compounds. The acid forming compounds cannot be removed but by the addition of an inhibitor, oxidation is prevented. The result is a turbine oil that will last indefinitely. A typical illustration of such an oil that has been used continuously in a 7500 kw. turbine follows:

Length of Service	Neutralization No.	Tag Robinson Color	Viscosity S.U. @ 100
Original Oil.....	0.03	21	150
11 Years.....	0.04	12	148

Another class of addition agents which have great merit are those materials which have been found so effective in Diesel engine lubricating oils and which are known as "solublizers". Solublizers are products which when used with properly selected oils prevent the deposition of partially oxidized and otherwise gummy and tarry products. They therefore function in a diffdrent way than do inhibitors. In this instance oxidation does occur but the products of oxidation do not separate or deposit to give the hard carbon, stuck rings, etc., so common in Diesel operation. In other words, the oxidation products are, in effect, kept in solution in the oil.

There are many addition agents which are worthy of discussion such as "oiliness" agents, or sulfur compounds such as are used to improve the efficiency of cutting oils and many others, any one of which is an interesting subject by itself. All of them, however, are striking examples of the importance of the application of chemistry to lubrication.

No paper on the chemistry of lubrication would be complete without some comments on that very controversial subject of extreme pressure lubricants. There have been many papers written and many theories expounded as to the why and how of E. P. Lubricants. Perhaps chemical compounds are formed on the metal surfaces or perhaps because of increased polarity there is increased resistance to rupture of the lubricating film, but regardless of the theory there is unquestionably some chemical reaction that permits greater pressures between rubbing surfaces without galling or scoring than can be withstood by straight mineral oils. Thus in this field which has done much to make possible improved designs the proper application of chemistry has resulted in progress.

Unquestionably the future will see increased concentration on the chemistry of lubrication and a continual improvement in the quality of the lubricants available to industry.

DISCUSSION

PRESENTED BY

F. L. GRAY, Test and Lubrication Engineer, Carnegie-Illinois Steel Corporation, Gary, Ind.

F. L. GRAY: Mr. Bowers has mentioned that the application of all knowledge, physical, mechanical and chemical increases the efficiency of lubrication.

We are only too familiar with the physical and mechanical aspects of the problems. Articles are written and papers discussed on these phases. But, to arrive at the answer to the question "why" such things happen, so that we may forsee our difficulties, we must apply more and more the knowledge gained by the chemist through research and experience into the practice of the mills.

For years our mills have been great users of an unfiltered still residue, cut back with a light oil distillate, and sold to us at a price that, on the face, would appear to bring about cheap lubrication. For want of a better name, it was given the color designation of Black Oil.

We used this oil in large quantities, allowing the excess to accumulate in the sewer. This eventually caused difficulties. The chemist has finally convinced us that a better grade of oil, sparingly used, and reused, can perform the operation more efficiently, more cheaply, and with cleaner and safer surroundings.

The chemist has not only been called upon to design oils and greases to efficiently and economically meet our demands but he must present a mechanical yardstick by which we might follow to derive the full benefits of his research and experience.

We are only too prone to accept the products of chemical research and neglect the yardstick of correct application and attention in mechanical use. It therefore behooves us to better understand the chemical characteristics of our lubricants that we might better apply more intelligent physical and mechanical knowledge to our mill lubrication.

Mr. Bower's comment on oil oxidation was very instructive. Few of us realize the vicious cycle of oxidation an oil goes through with every 20-degree rise in temperature. We have experienced an outstanding case. A circulating oil was heated to 180 degrees F. before filtering. The steam system was changed to supply 155 degrees superheated steam. Although the bath registered 180 degrees, the contact oil was much higher and teriffic oxidation resulted. In this case we did not change to a highly refined oil which would be resistant to the oxidation, but corrected the steam temperature.

The paper by Mr. Bowers has opened the way for a more complete understanding of the problems of lubrication. And may our future programs in the Lubrication Section bring us the knowledge that will enable us to keep abreast of the ever advancing art, "the elimination of unnecessary friction".

UMANSKY DISCUSSION

(*Continued from page 35*)

unit, particularly so inasmuch as this substation happens to be a connecting link in an interconnected power system, involving four (4) large public utilities.

There is one disadvantage of Mr. Umansky's method of starting a frequency converter by means of an auxiliary d-c motor, as applied to our system, or any system with a similar set-up. There have been occasions during the past when we have experienced a complete power interruption on our 25 cycle system and in order to get going are dependent upon purchased power, which means that the frequency converter must have its starting equipment on the 60 cycle motor end.

It might seem off hand that I am taking exception to Mr. Umansky's discussion in connection with the 25 to 60 cycle frequency converter, but quite to the contrary, I am merely citing our experiences as additional proof to strengthen Mr. Umansky's argument; namely, that the solution of the problems encountered in steel mill electrifications requires full recognition of all the possibilities and limitations of the equipment involved. Then and only then, can the equipment be tailor fitted to suit the job.

I want to make mention also of the fact that in connection with the installation of our frequency changer at Bethlehem, the set was furnished originally with a voltage regulator on the 60 cycle generator. The unit was put into service April 7th, 1935 and during the course of the next few months the growth of the plant load plus some difficulties encountered in our gas engine station produced rather poor voltage regulation on our main distribution system. A voltage regulator was installed on the 25 cycle generator the latter part of 1935, and its effect upon voltage regulation on our 25 cycle system was greatly improved, as a matter of fact, the regulation is extraordinarily good, considering that about a month ago, a 25-ton electric arc furnace was put into operation without any major changes being made in our main distribution system to accommodate same.

The effect of field forcing of synchronous motors and good voltage and power factor regulation on the operation of a power system with its associated equipment was very clearly illustrated in Mr. Umansky's paper and clears up many questionable points in the minds of ones not thoroughly conversant with hot strip mill electrical practices.

J. F. Headlee: Mr. Umansky mentioned that no one would start from "scratch" in the design and construction of steel mill electrical drives, as the large amount of data available reduces the problem to one of application. This reference brings to mind that a few years ago the electrical engineers of both the steel mills and electrical manufacturers were arduously engaged in figuring the required horsepower, type of motor, control and application of electrical drives. Each engineer had his own method of determining the requirements and wide variations were common in the determinations as given by the engineers. A large amount of credit is due to the Association of Iron and Steel Engineers for coordinating and disseminating data on electrical drives, so that today a great amount of valuable data is available to the engineers of the steel industries and electrical manufacturers.

This permits the engineers to devote more attention to special problems and refinements such as Mr. Umansky has described.

The first problem outlined in Mr. Umansky's paper illustrates how the steel mill engineer is often handicapped in planning for the ultimate installation because he does not know the extent or rapidity of plant development. He must be resourceful in readjusting his plans to meet new situations.

A very special problem may be presented in a grow-

ing plant by the addition of loads and generating facilities until a point has been reached where the original switchgear would not have adequate rupturing and short time current capacity.

The paper substantiates very clearly that engineers must be always alert and aggressive to develop equipment, methods, and facilities for increased economies in steel plant operations.

W. DUDLEY: Mr. Umansky has given in his usual clear and interesting fashion, rational solutions of four usual problems arising in connection with the application of electrical equipment to strip mills. Most of us will agree that the plans finally adopted in each case represents a much more desirable arrangement than would have been secured if precedent alone had been permitted to dicate the decision.

While Mr. Umansky's article primarily presents a very instructive study of four special problems involving electrical equipment, I feel his novel solution of those cases should encourage us all to a similar open minded approach to the many other puzzling questions which daily confront steel mill engineers. Over a short period of time these questions will not alone deal with electrical matters, but likewise in some degree they will deal with every phase of engineering involved in steel mill operations, as well as with human factors, and this may prove to be the most troublesome of the two.

It has not been many years since the tandem strip mill, as it is known today, was first introduced on a practical basis down in Ashland, Ky., and later in a form more closely approaching our present day design at Butler, Pa. It has been said that the continuous strip process involved in paper mill operations had considerable influence in the original conception of the idea. We may well consider whether in our day and age there has been a more daring and successful departure from standardized steel mill engineering, operating and production methods, than the pioneers of the wide strip mill exhibited when they transferred the fundamental processes of paper making to the production of steel strip. Had these men not broken from the conventional method of making sheet and strip, the four special problems described by Mr. Umansky would probably not have been presented in connection with strip mills.

In a greater or lesser degree similar fundamental departures from the conventional are continually occurring in all phases of steel mill engineering and operations, and unless we approach our particular phase of them in an open minded intelligent manner, we may be sure that the development of our mills will be stifled and we will soon find ourselves handicapped in meeting the ever increasing demands for betterment in economy, increase in production and improvements in quality.

To the outside observer of a steel plant, in its slow and gradual evolution, it may sometimes appear that it lies dormant during the major portion of its life, but if this is the actual case it may be certain the active life will be a short one. Advances in the art of steel making and in the multiplicity of devices necessary in its manufacture are continually forcing the necessity of change in some facility, and unless the changes are made within a reasonable time after the need develops, it will not be long before that plant is in trouble. These individual changes are frequently too small to command but limited attention from those outside the organization, but they are developing continually, and each one will justify careful consideration before blindly accepting previous developments as the solution best suited to meet local plant conditions.

In that portion of Mr. Umansky's article dealing with the frequency changer and the "Fewer and Bigger" M-G Sets, it is interesting to observe that the cost of switching equipment apparently was a deciding factor in the final choice of arrangement. It is not unusual to find the element of switching equipment costs exerting this same powerful influence in any major study of motor or power application, and need cause no surprise in this particular case. It does serve, however, to emphasize at this time what may be considered a more or less unfortunate condition, depending upon the point of view. At least it seems unfortunate to this commentator that such heavy expense and such great importance should necessarily be attached to a single piece of auxiliary equipment which at best operates only infrequently and the remainder of the time simply serves as a watchman and guard at the gate while the rotating equipment which it protects is actively engaged throughout the day in developing the earning power of the plant. Perhaps it is not voicing undue optimism to express the hope that some day the same type of unprejudiced approach which Mr. Umansky has well illustrated in his paper will be applied to the question of switching equipment costs and that some means will be found to bring them more in line with other pieces of electrical equipment which serve a more active purpose in production.

The two means of adjusting synchronous motor excitation to meet different operating requirements, which were described in the remainder of Mr. Umansky's paper, are of considerable interest. The use of a power factor regulator should be particularly valuable in those cases where variation of bus power factor below or above a given range would impose a penalty on purchased power rates or require materially increased investment in the feeder transmission system. It is suggested that a brief description of this device would be helpful if included with the article. The use of limit switches located ahead of the mill, for the purpose of applying increased excitation to the synchronous motor prior to the entrance of steel in the rolls, appears to be more desirable than the use of field forcing relays which only become operative when the motor input reaches a predetermined value. The limit switch method would insure that excitation of the desired value would be effective before the increased torque requirement developed, whereas the inherent operating characteristics of the field forcing relay permits the torque requirement to develop before the excitation can be increased. This seems such a simple and obvious arrangement it is surprising that it was not suggested when field forcing was first applied some eight or nine years ago. Without wishing to suggest too strongly the high degree of accuracy in hindsight, but only to follow the thought expressed in Mr. Umansky's preliminary remarks, it may not be out of order to suggest that perhaps some one followed conventional relay engineering somewhat persistently at that time.

VARIABLE SPEED TRANSMISSION APPLIED TO NORMALIZING FURNACE

▲ What is believed to be the first application of a mechanical variable speed transmission to a normalizing furnace has been made at Empire Sheet & Tin Plate Co., Mansfield, Ohio.

It has been general practice to use d.c. variable speed motors on these furnaces. However, only a limited amount of d.c. is available at Empire while the a.c. supply is unlimited. Furthermore, overhead cranes and other equipment are operated on the d.c. line and when this equipment is in operation a heavy load and drag are imposed with resultant drop in current and slowing down of all d.c. motors. Obviously, a sudden drop in current during a normalizing run would produce considerable variation in sheet quality.

For these reasons it was decided to install a Reeves variable speed transmission with constant speed a.c. motor drive. This not only saved the cost of running d.c. lines to the job, but also a considerable conversion loss, inasmuch as the 10 h.p. motor driving the transmission runs 24 hours daily, 300 days in the year.

This installation assures uniform speed for all normalizing runs, eliminating danger of sudden line-drop speed-drop. Also, maintenance on brushes and d.c. motor controls is saved.

The normalizing furnace was built by Flinn & Dreffein Co. of Chicago.

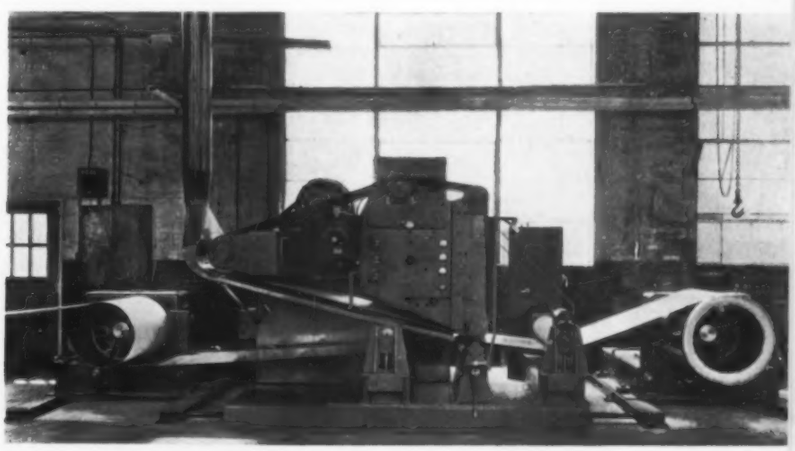
NEW GRINDING AND POLISHING UNIT

▲ Behr-Manning Corporation of Troy, New York have just installed in their plant a complete strip grinding and polishing unit for use with coated abrasive paper or cloth belts. This is the second unit this Company has installed in the last fifteen months for experimental and demonstration purposes, and it represents many new features as well as an entirely new design. It has a capacity for strip up to 30 in. wide.

The grinding and polishing unit built specially by the Hill Clutch Machine & Foundry Company of Cleveland includes a new automatic compressed air control for belt alignment; an automatic pressure control

Installation at Empire Sheet and Tin Plate Co., Mansfield, Ohio believed to be the first application of a mechanical variable speed transmission to a normalizing furnace

This complete strip grinding and polishing unit for use with coated abrasive paper or cloth belts has a capacity for strip up to 30" wide.



for grinding or polishing which permits a positive setting for fine grinding or polishing; an air control pressure for rough grinding and maximum stock removal wherein the head may float over irregular surfaces; an air actuated head which quickly makes or breaks the contact between the belt and the strip.

The passage of strip through the machine is at all times electrically under the control of the operator, all controls being mounted in the machine head within easy reach. A combination of reels by the Broden Construction Company and a special circuit, controls, motors and motor generator by Reliance Electric Company and Clark Controller Company complete this unit.

This set-up provides constant tension in nine steps from 200 pounds to 8,000 pounds as required, depending on the gauge and width of steel and may be regulated instantly while the machine is in operation. Likewise, the speed of the strip may be regulated to anything from seven to thirty-five feet per minute in the first stage or thirty to one hundred and fifty feet per minute in the second stage. In either range, the change may be made while the machine is in operation.

It is so designed that the operator has access to, and a clear vision of the strip entering the grinding area, to permit any necessary lubrication of the surface and to detect surface imperfections which may require extra grinding. In such cases, the strip may be instantly reversed, maintaining tension and speed merely by throwing a reversing switch, and this may be repeated until the imperfections have been removed.

The grinding unit may be used in conjunction with any type of reel with friction drag but the electrical control for strip speed and tension, it is claimed, is more positive and smoother in operation. This machine may be used for grinding hot or cold roll strip in the heavy gauges or for polishing down to .005.

Its purpose — to reclaim stock which because of surface imperfections cannot otherwise be satisfactorily rolled out; to improve cold rolled finishes and to produce a fine ground surface to match standard sheet finishes.

The Behr-Manning Corporation is inviting all manufacturers of, or fabricators using strip steel or other metals or alloys, to see a demonstration of this new equipment.

PRODUCING

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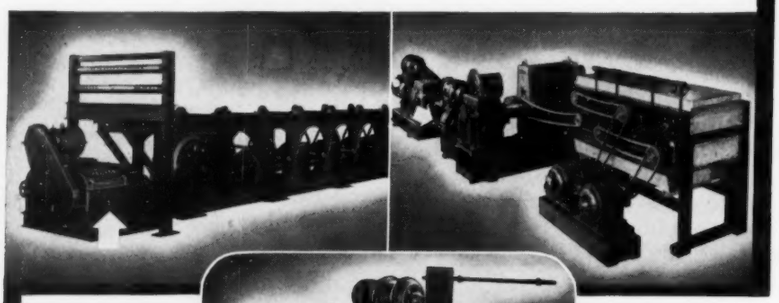

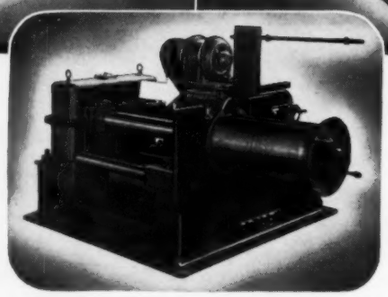

ABOVE: *Steel strip is drawn from annealing furnace and coiled on this* REEVES-*regulated patenting frame.*

ABOVE: *Removal from pickling vat and recoiling.*

LEFT: *Final wind-up before forming.*

• Typifying the manner in which the accuracy and positiveness of modern REEVES Speed Control units are rapidly gaining increased recognition and popularity in steel and steel products mills—consider the applications pictured above.

Operating on a. c., with no possibility of unwanted fluctuation from d. c. current drop—due to loads imposed by other equipment—REEVES VARIABLE SPEED TRANSMISSIONS permit quick and accurate changes of speed to be made on all three wire machines in order that different weights and widths of steel strips may be heat-treated, pickled and coiled on drums and spools with new precision, speed and economy. Modern REEVES units are easily applied and easily controlled, automatically or by handwheel. Perhaps you have a production problem that we can help you solve. Write us.

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REEVES SPEED CONTROL

IRVIN WORKS PIPING NEARS COMPLETION

▲ Blaw-Knox Company, through its Power Piping Division, is completing ahead of schedule the general mill piping for the new Irvin Works of Carnegie-Illinois Steel Corporation. This piping installation is one of the largest ever undertaken in connection with an industrial project. It involves about 60 miles of piping, ranging in size up to 48 inches in diameter, and includes lines for high and low pressure steam; filtered, raw and city water; hydraulic systems up to 3500 pounds pressure; air, fuel and acid supply; and circulating oil and grease systems. Most of the lines were prefabricated to facilitate the field work, and all lines were joined by electric welding except for connections at valves or to machinery equipment.

SAFETY AWARD TO JONES & LAUGHLIN

▲ A "Certificate of Merit" for a safety record in 1937 better than the average for the metal industry and several "Certificates of Honor" for departments with perfect safety records for the year have been awarded the Jones & Laughlin Steel Corporation by the Pennsylvania Department of Labor and Industry.

In a letter transmitting the coveted certificates George B. McDonough, Supervising Inspector of the Department said in part: "Your achievement for the year 1937 speaks for itself. It shows that the management and employees are vitally interested in Safety. . . . . We thank you for your fine cooperation and hope you will continue the splendid work".

TWO LARGE FURNACE CONTRACTS AWARDED

▲ Surface Combustion Corporation, Toledo, Ohio has announced receipt of two large contracts.

The first is a large sheet normalizing and blue annealing furnace for the new Irvin plant of the Carnegie-Illinois Steel Corp., subsidiary of the United States Steel Corporation. For normalizing, this furnace will have a capacity of 50 gross tons in eight hours. For blue annealing, the capacity will be 46,000 pounds per hour.

The other contract made with the United States government, is for two large stress relieving furnaces, one at the Brooklyn Navy Yard and the other at the Philadelphia Navy Yard. These furnaces are of the convection type, each with an hourly input of 16,000,000 Btu.

NEW LITERATURE

▲ De Laval Steam Turbine Company has reprinted an article, written by H. W. Graham of the Dravo Corporation, entitled: "Pumping Water for Descaling Spray", for distribution to the industry. This article describes a pumping system for this service at the plant for the Youngstown Sheet and Tube Company.

If you desire to read this interesting technical article we suggest that you write to the De Laval Steam Turbine Company, Trenton, New Jersey.

▲ Hagan Corporation has recently published an attractive brochure entitled: "Hagan Automatic Combustion Control". This beautifully designed booklet tells a complete story on the subject, and describes the application of control to various types of fuel-fired boilers. Illustrated throughout with diagrams, and typical installations, the book should make a valuable addition to your files.

Hagan Corporation is located in the Bowman Building, Pittsburgh.

▲ Appleton Electric Company has published a 64-page bulletin illustrating Appleton outlet and switch boxes, conduit fittings, etc.

Write for Bulletin No. 1022, by addressing the Appleton Electric Company, 1701-29 Wellington Avenue, Chicago, Illinois.

NEW – USEFUL INFORMATION on GEARS and GEAR UNITS–FREE

All users of gears and gear units will find much valuable information in our new Catalog No. 438, just published.

It contains instructive chapters on practical features of gear design and the advantages of herringbone gears for transmitting power and transforming speed between parallel shafts.

Included are twenty illustrated pages describing a complete series of speed reducing gear units, accompanied by tables of horsepower ratings, service factors, overhung load capacities, dimensions and weights. Similar descriptive and engineering data are given on speed increasing units, vertical reduction units of the horizontal shaft type and right angle vertical shaft drives.

In addition, many special-purpose units are illustrated and described. Among these are high-ratio drives, multi-speed gear units, right angle horizontal shaft units, rolling mill drives and pinion stands, dredge drives and marine propulsion units.

It is an engineering handbook which will be found useful by all who use gears and gear units.

Complimentary copies may be secured by plant executives and engineers who will write on their company letterhead to the address below.

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FARREL SYKES GEARS — *The Gear with a Backbone*

ITEMS OF INTEREST

R. B. Gerhardt, formerly assistant chief engineer of construction at Bethlehem Steel Company, Bethlehem, Pennsylvania, succeeds A. T. Keller as chief engineer of construction at this plant. Mr. Gerhardt, a native of Martinsburg, West Virginia, was graduated from Cornell in 1907. He started with Bethlehem in the electrical department of the Steelton plant, later being promoted to superintendent of the electrical department at Sparrows Point. In 1923, he was appointed assistant general manager of the Maryland plant, and in 1928 was transferred to the Steelton plant as assistant general manager, going to Bethlehem in December, 1936, as assistant chief engineer of construction.

Mr. Gerhardt has been a member of the Association of Iron and Steel Engineers for twenty-two years, serving as president in 1923.

▲

A. T. Keller, chief engineer of construction, Bethlehem Steel Company, Bethlehem, Pennsylvania, and for fifty years a leading engineer of the Steel Industry, will retire from active service September 1. Mr. Keller, a native of Pittsburgh, started as a draftsman in 1888. He was initially with Mackintosh-Hemphill Company, Mesta Machine Company, and was chief engineer of the Gary Works of the United States Steel Corporation, during the construction of that plant. Going to the Maryland Plant of the Bethlehem Steel Company at Sparrows Point, Maryland, in 1916 as chief engineer in charge of the rebuilding and expansion program there, he was transferred in 1920 to Bethlehem as chief engineer of construction for all the plants of Bethlehem Steel Company.

▲

G. S. Comstock, superintendent of power and maintenance at Bethlehem Steel Company, Steelton, Pennsylvania, will succeed R. B. Gerhardt as assistant chief engineer of construction at the Bethlehem Works. Mr. Comstock started with Bethlehem in 1917, in the mechanical department of the Bethlehem plant. He was then transferred to Steelton as assistant mechanical engineer, and at present is superintendent of power and maintenance at Steelton.

▲

Newbold C. Goin succeeds L. R. Botsai as sales manager of the Westinghouse Electric and Manufacturing Company's gearing division, Nuttall Works, Pittsburgh, Pennsylvania. Mr. Botsai was recently transferred to the sales managership of the company's small motor division at Lima, Ohio. Mr. Goin, born in Lemont, Illinois, in 1895, has been associated with Westinghouse since 1917. He has been employed as a field service engineer in the southeastern and central districts and since 1924 has been a salesman in the central district. Mr. Goin has been a member of the Association of Iron and Steel Engineers since 1925.

▲

Robert Gilmore was made general manager of the new Jones and Laughlin Steel Corporation wire rope plant at Muncy, Lycoming County, Pennsylvania. Mr. Gilmore, whose entire business experience has been in the wire rope field, will direct and supervise fabrication and sale of the products of the new plant. This new plant, known as the Gilmore Wire Rope Division of the Jones and Laughlin Steel Corporation, marks the entry of this company into a new line of finished products including wire rope for oil country use, for general construction purposes and for industrial applications.

▲

J. W. Berscheid, superintendent of the Fairfield Wire works Tennessee Coal, Iron & Railroad Company Birmingham, Alabama, since June 1, 1931, has announced his retirement.

Mr. Berscheid, who has forty eight years of uninterrupted service with subsidiaries of the United States Steel Corporation began as a water boy, working his

R. B. GERHARDT

N. C. GOIN

ROBERT GILMORE

way up through the various positions in the wire and nail manufacturing industry. He is credited with developing several valuable improvements now employed by the corporation in its wire and nail plants. He joined the corporation at the Illinois Steel Company, Joliet, Illinois, in 1890. He went to the Lambert and Bishop Wire Fence Company, in Joliet, as a nail machine helper and operator in 1891, remaining until 1896, when he went to the Consolidated Steel and Wire Company, as a nail operator in the Beaver Falls, Pa., works, and after a short period there, returned to Joliet as a nail operator for the Laidlaw Bale Tie Company. Shortly afterward, he was employed by the Consolidated Barbed Wire Company of Illinois as a foreman in the nail mill of the Bluff Street works, at Joliet. In 1899, he joined the American Steel and Wire Company, as general night foreman at the Rockdale works. Numerous promotions followed, and in 1931 he was sent to Birmingham to take charge of the Fairfield plant.

▲

Jacob J. Phifer, who has been in the service of the United States Steel Corporation since February, 1920, and who was transferred to the Fairfield Wire works as assistant superintendent January 1, of the current year, succeeds Mr. Berscheid. Mr. Phifer received his early training in Lehigh university and at the foremen training school of the American Steel and Wire Company.

▲

Calvin Verity was recently elected as executive vice president and general manager of the American Rolling Mill Company, Middletown, Ohio. Mr. Verity first started to work at the American Rolling Mill Company as a high school boy during vacations. On graduating from Cornell University, his first regular job was on the night shift in the boiler house in 1911. Later he became boiler house foreman, assistant superintendent of power, construction foreman, and millwright.

After service in the World War, Mr. Verity returned to the American Rolling Mill Company, and was placed in charge of the industrial engineering department, dealing with problems of scheduling and production. On May 1, 1921, he was elected treasurer of the company, and in 1926 became assistant general manager, in addition to his responsibilities as treasurer. He was elected vice president and assistant general manager in 1930, and in 1933 executive vice president and assistant general manager.

▲

W. W. Sebald was elected vice president and assistant general manager of the American Rolling Mill Company, Middletown, Ohio. Mr. Sebald, who for several years has been Armco's vice president in charge of commercial activities, after leaving Middletown High School, began work in a Middletown bank as office boy. Two years later, in 1906, he quit his job in the bank to become an office boy with the American Rolling Mill Company.

Learning the routine of sales activities by actual experience he soon became a salesman for the company, and in 1912, was appointed as manager of the New York sales offices. Returning to the general offices of the company in Middletown in 1919, Mr. Sebald was made assistant general manager of sales. In 1924, he was made assistant vice president, and on July 1, 1926, vice president.

▲

Dudley D. Pendleton is now sales representative for the Buell Engineering Company, Inc., with his headquarters in the Koppers Building, Pittsburgh, Pennsylvania. Mr. Pendleton's territory includes Western Pennsylvania, West Virginia, and Eastern Ohio.

▲

George P. Wardley, who was appointed assistant director of industrial relations for Carnegie-Illinois Steel Corporation, was recently tendered a banquet in his honor. Tribute was paid Mr. Wardley by B. M. Livezey, W. E. Hadley, E. E. Moore, J. M. Darbaker, and H. A. Strain, who are officials at the South Works, where Mr. Wardley was formerly located as superintendent of industrial relations.

▲

A. F. White, who has been superintendent of the steel works of the American Steel and Wire Company at Donora, Pennsylvania, was made general superintendent of the newly consolidated plants of that company. J. C. Witherspoon, heretofore superintendent of steel production, will become assistant general superintendent, in charge of blast furnaces, open hearth and blooming and billet mills.

▲

C. J. Brown, who was formerly superintendent of the Donora Wire Works of the American Steel and Wire Company, has been transferred to the Rankin Works as superintendent. Mr. Brown succeeds E. R. Patterson, who will become assistant general superintendent at Donora, Pennsylvania.

▲

A. D. Brophie has been transferred from the Detroit office of the Jones and Laughlin Steel Corporation to the Pittsburgh district. Mr. Brophie will be the cold mill superintendent at Jones and Laughlin's new hot and cold strip mill.

▲

Andrew W. Soderberg, who, as announced in our May issue, retired from his duties as chief engineer of the Homestead Works, Carnegie-Illinois Steel Corporation, has become affiliated with United Engineering and Foundry Company, Pittsburgh, Pennsylvania, in the capacity of consulting engineer. Mr. Soderberg, originator of the "rocking chair" principle for cutting wide steel plate, was born in Sweden May 31, 1868, and was educated in the public schools there, and in the United States. He was employed at Homestead by the former Carnegie Steel Company, December 2, 1889, and in 1902, became assistant chief mechanical engineer. He was appointed chief mechanical engineer in 1915, and chief engineer in 1937, holding the latter position until his recent retirement from active service.

Mr. Soderberg is a member of both the Association of Iron and Steel Engineers, and the American Iron and Steel Institute.

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